THE

HISTORY AND SCIENCE

OF

IRRIGATION,

ARTESIAN AND PETROLEUM

AND DEEP

WELL DRILLING.

By ROBERT KITTLE

FREMONT, NEB.

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PREFACE.

THE AUTHOR, in offering this little book to a generous public, hopes to furnish suggestions of the best means for irrigation by surface and underflow waters; for drilling artesian wells, and gas and oil wells.

Look for what you want by reading the whole work and by the examination of chapters and sections according to the Contents.

EDUCATIONAL.

1. A First Book in Geology. Volcanism and Sismology.
2. A Text Book on Systematic and Practical Geology. for Colleges.
3. A Standard Geological Chart, Teachers' Ready Reference.
4. History and Science of Irrigation, Artesian and Petroleum Well Drilling.

FOR POPULAR READING.

5. A Summary of the Geological Ages.

Mr. Kittle is the Author of the above series of books. Revised and corrected by Mrs. M. A. Kittle.

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THE HISTORY AND SCIENCE OF IRRIGATION

—AND OF—

DEEP WELL DRILLING FOR WATER, GAS AND PETROLEUM.

INTRODUCTION.

Section 1.—1. The great plains, semi-arid, arid, and desert lands in this and other nations makes the study of the science of irrigation and deep well drilling *of the greatest importance to mankind* for the discovery of flows of artesian water, gas, petroleum and any other valuable minerals, which may be buried under the surface in the stratified rocks, and which might add to the means necessary for the support of an enlightened and civilized people; where otherwise there must forever exist only desert regions, unfit for human habitation.

2. These regions, it is confidently believed, can be made susceptible of supporting a very dense population of intelligent and happy people in comfort, plenty, wealth and general prosperity, by methods of irrigation and judicious cultivation of small irrigated farms, by the use of the natural water supply from precipitation and under-flow reached by wells. And by utilizing natural gas, petroleum, and other minerals which may be found here, as sources of wealth, together with all the means for the production and growth of all agricultural and horticultural vegetation. Suitable soil and a certain amount of water and sunshine is naturally required.

3. The water may come to the seeds and plants by precipitation, percolation or capillary attraction from natural causes sufficiently, or only partially sufficient,

always be of great interest to the horticulturist and agriculturist, to understand the proportions to each other, with which these naturally unite in the several plants, desired to be grown; and whether there is to be found in the soil, where the plant is to be grown, all the natural elements needed, or whether some one or more must be supplied as a fertilizer; and the most economical method and condition under which to apply it.

3. Irrigation always assists the operations of solving the plant-food existing in the soil, to sustain its life and growth. The moisture furnished by irrigation in a special manner sets free the carbon and nitrogen otherwise held in solid compounds.

4. "Liquid nitrate of soda is said to be one of the best manures which may be mixed with bone black.

5. But the farmer who places a tank or cistern so that all the animal *urine* from his stalls will be caught and saved, to be sprinkled on his crops, particularly on early garden vegetables, will find that this manure will equal the nitrate of soda as a fertilizer.

6. Liquid urinic manure, as above, saved from *one cow*, as an experiment, made for one year, in Denmark, showed that of 194 pounds of nitrogen, contained in the food consumed, forty-five and one-fifth pounds went into her milk, and seventy-three and three-fourths pounds went into her urine."—(*Rural New Yorker.*)

7. Frank G. Carpenter, in a letter dated May, 1894, from Chinkiang, China, says that "Everything is saved. Thousands of men do nothing else but gather up bits of fertilizers and sell them. The refuse of a rich family will bring more than that of a poor one, and the slops of the foreign part of Shanghai are farmed out annually for a sum which gives the city the most of its educational fund. Potato peelings, the parings of finger nails, the shavings of the head form parts of the fertilizing material, and this is usually put

together in such liquid form that not a bit of it is wasted. The manure is kept in great vats and the farm is watered like a garden. Each plat gets its daily food and drink. A dipper full from the vat is put into each bucket of water and the mixture is poured in at the roots of the plants.

8. All over, throughout this part of China, such fertilization goes on, and from $20 to $30 a year is sometimes spent on an acre of land." But here are acre farms; some holdings of one-tenth of an acre, supporting families often of six persons.

CHAPTER II.

THE HISTORY OF IRRIGATION.

SECTION 1.—1. It is FIRST necessary to have some general knowledge of the history of irrigation to well appreciate its practical methods and its great value.

IRRIGATION BEGAN IN EDEN.

2. Before it had been said unto Adam "That in the sweat of thy face shalt thou eat thy bread." (3d Gen. 19). "The Lord planted a garden eastward of Eden, and there He put man whom he had formed.

And a river went out of Eden to water the garden." (2d Gen. 8:10).

From such a record it seems that in cultivating the Garden of Eden, Adam had to irrigate or water the garden with water taken from the river.

IRRIGATION IN EGYPT.

3. During the reign of King Moeris (B. C. 2084) for the purposes of utilizing the annual overflow of the Nile River, and for the storage of the surplus water.

4. The king had a great storage reservoir con-

structed which has ever since been called after the name of the king and is still known as Lake Moeris.

5. Its circumference is 3,600 stadia, equal to 2,184,300 feet—413$\frac{183}{264}$ miles.

6. This king, to make it evident to all future generations, that this lake was an artificial work and not the work of natural causes, or of "any god;" he, before the water was let into it, caused two great pyramids to be founded and built in and below its bottom; and to the height of three hundred feet on each of which he caused a throne to be built. (As the length and breadth are not given of the lake it may have occupied a portion of a canon or valley).

7. "The main canal by which this lake was filled and supplied with water led from the Nile to the lake, a distance of 32 miles, having a width of 50 feet.

And it was constructed with sluices, so that these could be opened and closed as occasion may require, to regulate the quantity of water and irrigate the land.

9. Fish, by the king's command had been planted in Lake Moeris, which not only supplied the monarch's table, but also yielded him a large revenue.

10. At the time when Lake Moeris was constructed, Egypt contained 20,000 cities. One of these cities had 100 gates, with sufficient population, so that out of each of these several gates could be sent 10,000 soldiers at the same moment; an army of 1,000,000 soldiers." —(*Rollin.*)

IRRIGATION IN INDIA.

Section 2.—1. "The great reservoir which was built about 1500 A. D., in India, has since been partly destroyed. It was built for irrigation purposes, and known as the Muduk Tank. The embankments forming it were 110 feet high, 1,000 feet wide at their base. The inner slopes were as 1 to 2½, to 1 to 3. And they were riveted with large bowlders. When filled its greatest depth of water was 95 feet."

COST AND MAGNITUDE OF IRRIGATION IN INDIA.

2. In the early part of the present century it was estimated that England had expended in India for irrigation purposes $165,000,000.

3. And had built reservoirs and canals which were sufficient to supply water for the irrigation of 15,000,000 acres of arid lands.

"And now have tanks, reservoirs and canals within the Presidency of Madra alone to irrigate 20,000,000 acres.

THE RAVERI RIVER

4. Is made to irrigate at its delta 9,000,000 acres; supplying in each second of time one cubic foot of water on each 66 acres," which is equal to more than 3,568 cubic feet of water on each acre every hour, which if wholly used would cover the irrigated land over eleven inches deep. "The maximum flow of the water in the river is 280,000 cubic feet per second."

"THE GORDOVARI RIVER."

5. "This river discharges 1,210,000 cubic feet per second. Here $7,250,000 has been expended, and for the irrigation of 670,000 acres, which produce two crops each year. But these irrigation works are yet unfinished.

6. We have mentioned only these river irrigation works in India, still there are too many other rivers and waters there, which have been and are being utilized for irrigation, to now be specially mentioned. Some others of India's irrigation works will be noticed further on, when we speak of the various engineering irrigation methods, etc.

THE ANCIENT KINGDOMS IRRIGATED.

SECTION 3.—1. "To know that irrigation has been extensively practiced in the great kingdoms that have risen and fallen in past ages, and practiced in each of

them while their civilization was at its greatest heights, should stimulate our consideration of its importance.

2. It is a well attested historical fact that irrigation was practiced anciently and still in some of the states of Babylonia, Assyria, Persia, Palestine, Syria, Asia, Egypt, Morocco and other parts of Africa, in Greece, Rome, Spain, Gaul, France, and in England.

3. "And by the prehistoric people in North and South America; by the 'Incas,' old Peruvians, the Aztecs, Montezumas, in Mexico, New Mexico, Arizona and Kansas.—(*Senator Cross, et al.*)

4. "IRRIGATION in France, Spain, Germany, and extending into Algeria, Africa, is now offering great opportunities to people desiring to acquire homes."—(*Leon Philippe, French Chief Engineer of Irrigation.*)

IRRIGATION IN ITALY.

SECTION 4.—1. The Italian government claims to have the grandest, or one of the grandest irrigation canals in the world; it is in the province of Cavour. It has in its construction a siphon of solid masonry 870 feet long, and several solid masonry aqueducts; one of these is 635 feet long.

IRRIGATION IN RUSSIA.

2. Russia has 3,600,000 square miles of arid but irrigable lands; of these only about 494,200 acres have yet been irrigated, which has cost for the irrigation from $6.00 to $12.00 per acre."

IRRIGATION IN PERU.

3. "An interesting spectacle in Peru is the remains of old Inca terraces and irrigation canals on the hill-sides, now apparently utterly unpromising deserts.

4. "While but a few years ago John Meiggs restored a canal along the side of the hills bounding the Rio Santa (Sant River) and there established a valuable property, which the writer saw as it grew from a desert into a grand plantation of immense proportions,

containing the greatest sugar-making machinery then in the world, and valued at $5,000,000."—(*From paper by Delegate Edward F. Sears for Peru at International Irrigation Congress, 1893.*)

IRRIGATION IN MEXICO.

5. There has been much good irrigation work done in Old Mexico; but as we shall have occasion to mention it in connection with specific methods we will not now notice it further.

IRRIGATION IN THE UNITED STATES.

SECTION 4.—1. "The subject of irrigation in the United States is of such great importance as to involve the consideration of the possibility of the settlement of two-fifths of the whole area of our country, which is arid land; the arid regions covering the great plains and nearly all the country west of the 97 meridian, and by the General Land Office estimated to contain 542,000,000 acres." — (*R. J. Hinton and Judge Gregory.*)

2. It has been estimated that these lands can be so improved by irrigation that they will be capable of sustaining and furnishing farm homes for millions of people, probably double the number of our present population, which would be a result worthy of the best efforts of our greatest statesmen and most patriotic citizens.

PREHISTORIC IRRIGATION IN THIS COUNTRY.

3. "The remains of prehistoric irrigation works have been found in New Mexico, Arizona, and some other southwestern states. These remains point back to a much higher civilization than that of the American Indian's, when this continent was first settled."

EXISTING IRRIGATION WORKS.

4. Within the last two decades there has been many and extensive irrigation works begun and completed in Oregon, California, Colorado, Idaho, Montana, Wyo-

ming, Nevada, New Mexico, Arizona, Kansas, Nebraska, North Dakota, South Dakota, Utah and Washington states.

5. And as we proceed in speaking of irrigation engineering and methods we shall notice these works in several states.

6. "In prehistoric times Arizona had large irrigation canals and large cities which are now found in ruins, that indicate a high state of civilization and prosperity at a time when these canals were constructed and in operation."--(*J. R. Rice.*)

THE EDGEMONT CANAL.

5. "Nebraska and Colorado are not the only states where the irrigation idea is bearing fruit. South Dakota has swung into line in a royal fashion; $60,000 are now being expended in the construction of an irrigating and power canal, near Edgemont, in that state. The canal begins at the confluence of Beaver creek and the Cheyenne river, fourteen miles northwest of the town; traverses nineteen sections of land; enriches 10,000 acres of splendid land, and has a final fall at Edgemont of seventy-two feet."—(*Western American, June 1894, page 14.*)

CHAPTER III.

MEANS AND METHODS OF IRRIGATION.

CATCH DRAINS.

SECTION 1.—1. To catch the drainage from the higher table lands, and from upper valley lands, and to lead their surplus and waste waters upon lower levels of arid and semi-arid land during the growing seasons for crops, it has for many centuries been the practice in Egypt, Persia and India

to construct dams and ditches at and from swampy valleys, heads of draws and ravines; and embankments along near the crests and slopes of hills and mountains. And from swamps, and catch meadows make dikes, ditches, canals and aqueducts, leading to lands needing irrigation, and there using the water, distributing it over the crops during the growing seasons.

CAPACITY OF DITCHES AND CANALS.

SECTION 2.—1. Irrigation ditches "and canals should be able to carry one cubic foot of water per second for each fifty-six acres to be irrigated by it, and three cubic feet for each section one mile square to be irrigated."—(*Charles W. Irish.*)

2. The Russian Irrigation Engineer says that "about one cubic foot of water in a second is sufficient for 70 acres of land." Probably this will do after three to five years of irrigation.

3. We will have several conditions to consider as to necessary quantity of water required for practical irrigation not mentioned in the above rules.

4. DITCHES AND CANALS are, or should be constructed so as to carry a given number of cubic feet (or as sometimes expressed by miners, "acre inches") per second, minute, hour, day, month, or growing season, of water.

5. Narrow and shallow ditches impede the flow of water through them, by reason of greater friction upon the sides, slopes and bottoms, more than do the large canals carrying deeper, wider and greater flows of water.

FALL OF GRADES FOR CANALS.

SECTION 3.—1. Two CANALS having the same grade, the one which is widest, deepest and carrying the greatest body of water will have the most rapid current, and deliver in proportion to the area of their sections of water flow, a greater amount of water per second.

2. But a properly constructed small ditch down a steep mountain grade may deliver a greater supply of water than a much larger canal having but little fall in its grade.

DITCHES AND THE INDIA TANK SYSTEM.

Sec. 4.—1. As the supply for the irrigation of any given tract of land must come from a tank, reservoir, lake or running stream, the water must be found some place. Naturally at such higher level, or be forced up by artesian wells, or raised by artificial power to such higher level, before the water can well be distributed over the land to be irrigated.

CHAPTER IV.

NATURAL WATER SUPPLY.

Section 1.—1. The natural water supply for all irrigation purposes, must have first come from natural seas and oceans. First having been evaporated, carried as mist and clouds by the winds over the land and mountains and there, by rain and snow been precipitated upon the earth as fresh water, this distilled from what otherwise would have been saline water and unfit for irrigation purposes.

TO SAVE THE WASTE AND WINTER WATER PRECIPITATION.

2. Dams may be constructed across near the heads of dry draws, ravines, canons and small mountain streams, thus forming tanks, basins and reservoirs large enough to hold ALL the water that may fall upon, or run from the higher levels than that of dams and reservoirs, during the year. To be conducted by ditches, canals and aqueducts to the highest parts of the lands and fields to be irrigated thereby.

3. These ditches, canals and aqueducts should be graded so as to have a fall of not less than one foot per mile.

RAIN AND MELTING SNOWS ON MOUNTAINS.

SEC. 2.—1. The precipitation of water on the upturned, broken and porous strata of hill and mountain ranges and chains, often, perhaps generally, enters into the porous strata to a far greater percentage than what runs away as mountain streams. The water so entering into the earth forms what we call UNDERFLOWS, which may be tapped by aqueducts, pipes, wells and artesian wells, so as to be lifted, pumped or conducted to the surface at localities, for irrigation and other purposes, to which surface waters could not economically be brought.

WINTER IRRIGATION.

2. Land well plowed, cross-furrowed, with shallow basins left on it in the fall, will absorb and retain the winter precipitation and running waters over it, serving as an early spring irrigation.

THE UNDERFLOW OF THE GREAT PLAINS REGION.

SEC. 3.—1. JUST UNDER THE CENOZOIC FORMATIONS, which are generally the surface of the great plains and arid regions of the United States, as over the whole of those regions on the American continents, which were formed at the time that coast chains and Rocky mountain ranges were lifted above the oceans.

2. There was formed from the shattered fragments of these mountain uplifts a porous stratum of bowlders, gravel and sands, in which there is now an inexhaustable supply of water within, as a rule, not exceeding 300 feet below the surface, and most frequently within from 10 to 150 feet of the surface, that may be pumped or lead by its own gravity through sewer piping and aqueducts to the surface at a small expense, or within

a few miles from the head of the aqueduct or ditch at greater expense and for greater distances.

3. The city of Fremont, Neb., takes water by piping from this stratum to flush its sewerage, and by pumps and drive wells obtains sufficient to supply families and the fire department with all that is now needed; the drive wells being all driven within less than a half acre of land.

ARIZONA IRRIGATION.

4. Arizona has 300,000 acres under irrigation, and along the Gila river valley there are other 300,000 acres which was in prehistoric times irrigated; where are found the remains of ruined irrigation ditches which should be rebuilt. Besides these lands there are large bodies of arid and semi-arid lands which might and should be reclaimed by irrigation along the valley of the Santa Rosa river.

NEW MEXICO.

5. There are in New Mexico evidences of prehistoric irrigation, and great tracts of arid lands which may yet be reclaimed. The present population are doing good work in the way of irrigation where enterprising and thrifty communities flourish.

CHAPTER V.

BASINS, DAMS AND CANALS.

SECTION 1.—1. Where a RUNNING STREAM furnishes the water to be used for irrigation, it is usual to construct the head works of an irrigation canal at a point on the stream sufficiently above the highest level of the land to be irrigated to admit of a grade for the ditch or canal, having a fall of not less than about one foot to the mile.

ARTIFICIAL BASINS.

2. Along on the valleys of rivers, where the bed of the river is found to be formed of coarse sand, gravel and bowlders, there often are found natural basins some ten to forty rods, more or less, back from the immediate banks of the river, covering several acres, as small lakes. Where such basins, or lakes, do not occur naturally along in the bottom lands, like those of the Platte river, they may be excavated to a depth of from four to six or ten feet below the surface of the river, covering from three to fifteen acres, to connect with the irrigation ditch, and they will supply water sufficiently from underflow.

3. SMALL DAMS may be constructed of earthworks across heads of ravines and dry runs to catch and reserve storm waters; and hold them for irrigation purposes, to be used during the growing seasons. Small streams and spring waters may in like manner be held and used.

5. RIVERS AND LARGE CREEKS may, in some places, where their bottoms and banks are formed of clay and gravel, or of bowlder clay, be dammed with such material. But these and all other earthworks for irrigation purposes should have very broad bases, and be raised to several feet above high water mark, thoroughly saturated with water, where they cross streams, and tamped while in the process of construction.

6. WASTE-WEIRS of sufficient breadth to allow all overflow and excess of waters to pass below the lowest top parts of dams and embankments should be constructed. All waste-weirs should be protected by thorough revetment or solid masonry. REVETMENT may be constructed of cobble stones, bowlders, rubble rocks, or of vitrified bricks, and should be from one and one-half to three feet thick.

7. WING DAMS should be used when it is only necessary to take a part of the waters of a running

stream to sufficiently fill the ditches, canals and reservoirs of some local irrigation system.

8. THE SLOPES of irrigation works, in the way of embankments, should never be less than twice the spread of the base to one of height, or as 1 to 2, on the inner slopes of the embankments; and 1 to 3, or 1 to 4, will be better and safer.

MASONRY; ROCK WÓRK.

SECTION 2.—1. SOLID MASONRY will in many places be required on large and rapid running waters, in the construction of wing dams, dams, canals, piers and aqueducts, and waste weirs and reservoirs to control large bodies of rapid running water.

BORDOS (Spanish for) DAMS.

2. DON JOSE RAMON DE YBARROLA, Chief of the Mexican Irrigation Engineers, said: "That a ditch to take the overflow waters from the City of Mexico, which is 8 miles long and 250 feet deep at its greatest depths, and averaging about 125 feet deep.

3. And to construct it required the removal of 850,000,000 cubic feet of earth, which was carried in baskets by the natives, on their backs, at the expense of the government.

4. Irrigation in Mexico is accomplished by the construction of bordos and embankments built from 10 to 25 feet high."

WHEAT IRRIGATION IN MEXICO.

SECTION 3.—1. To irrigate land for the raising of a wheat crop, sown from the middle of September to the middle of October, the *first* irrigation to stimulate germination, is run on immediately after the seed has been sown; then after from four to six weeks later a *second* irrigation is applied, and then a *third* when the plant is full grown, to make the grain fill.

CORN IRRIGATION IN MEXICO.

SECTION 4.—1. After the bordos have been emptied for wheat irrigation, they retain sufficient moisture to grow a crop of corn which is then planted in their bottoms.

2. These bordos have generally been constructed at the expense of the land owners.

In one case a Mexican landlord irrigated 56 square miles of his own land.

3. But by a general system of irrigation the Mexican government provides water ready to be applied, to the land which has been prepared and *divided into lots*, about 2,000 feet long, or less. Then at the proper time these are filled with water, and then they are left to soak from eight to ten days.

WATER STORAGE.

SECTION 5.—1. The water having before been run, or collected in bordos on the middle of September to the middle of October, for use, and a month later there is found no signs of water on the soil.

2. Then in November this ground is thinly plowed and press-rolled, and so left until March when cotton seed is sown.

IRRIGATION FOR THE COTTON CROPS, AND OTHERS.

SECTION 6.—1. The production of cotton, wheat, barley and other crops are greatly increased by irrigation.

MEXICAN METHODS, CONTINUED.

SECTION 7.—1. The Mexican methods vary but little from those of other countries in obtaining and storing water supplies for irrigation.

Bordos, catch dams, wing dams, reservoirs, ditches, canals and aqueducts, are there constructed for irrigating.

MASONRY AND ROCK DAMS.

2. Where dams are to be constructed to hold deep

deep and large bodies of water, to dam large and rapid running streams and rivers, they should be built with solid masonry, and of sufficient width of base to give them slope at an angle of 45 degrees, or slope of 1 to 1, but it will be better, where the strain is liable at times to be very severe, to make the inner slopes with a rise of 1 foot to a batter of $1\frac{1}{2}$ feet, or 1 to 2 feet.

IN INDIA.

SECTION 8.—1. Such solid masonry was worked in the building of an irrigation dam in 1500 A. D., and it was destroyed more than a century ago by an excessive water flow, coming by reason of a waterspout, above the dam.

2. INDIA of our times is credited with being in advance of all other countries in the extent, strength, and success of her irrigation works, of which we shall make further notice.

CHAPTER VI.

RESERVOIRS: NATURAL AND SEMI-ARTIFICIAL.

SECTION 1.—1. Natural reservoirs of water occur, which by more or less damming, ditching and other artificial improvements, have been and may be used for irrigation.

2. We may notice among these snow and ice, on the higher levels, in dams, lakes and mountain tops, and in the heights of perpetual frost. Snow, neve and glaciers occurring in canons, draws and in folds and basins of older and uplifted strata.

3. The ever melting snow and ice at the deep bottoms of these, form perpetual streams of running waters and underflows.

4. The same as do the mountain ponds and lakes

below the frost line, as so many natural reservoirs in and on the earth, and generally near enough to the parched, arid and thirsty fields of the great plains regions below, to be utilized for the purposes of irrigation, when tapped and conducted to these fields.

THE SUFFICIENCY OF NATURAL WATER SUPPLY.

SEC. 2.—1. The natural water supply for all irrigation and other purposes on land, has its origin and source, *first*, in evaporation; *second*, mist and clouds; and *third*, in measurable precipitation.

2. Evaporation is chiefly produced from the heat of the sun falling upon the water and moist land surface of the earth; with effects in proportion nearly corresponding, *first*, to the area of any given surface; *second*, to the relative directness with which the sun's rays impinge.

3. THIRD, the greater or less density of the pure *air*. The greater density being near the sea levels; the least density at the highest mountain summits.

4. FOURTH, mists and clouds are only lifted and carried upward by air that has a greater weight, and hence density, at the time and place where evaporated and lifted, than that of the heated and evaporated vapors.

5. FIFTH, When mists and clouds rise to heights where the air is so attenuate as to be less dense than the vaporic mists and clouds it can rise no higher.

6. SIXTH. Even the most powerful rays of the sun lose their main force in the upper strata of the air for the want of elements and density to act upon, in so very attenuated and ethereal material, which for this cause, ever marks a perpetual frost line at given heights, and in a certain stratum of high air, which is therefore *always cold*.

7. PRECIPITATION will *always* begin where the air reached by mist and clouds shall be either too attenuated

for its support, or too cold to continue in vapor, the water of which these were originally formed.

8. Even the air, which has also been expanded by heat, sufficient to permit the water to mingle in it, as misty vapor while warm, when cold contracts, condenses and refuses to longer support the condensed and liquid water, permitted to mingle with it, while in a gaseous fluid, so then precipitation must begin, in the form of rain, hail and snow, in the upper cold and thin air.

9. So in the temperate zones at the heights of about 10,000 to 11,000 feet, all the water carried to these heights must be precipitated upon the lands as rain, hail or snow water.

10. And while there is nearly three-fourths of the earth's surface covered by water, there should be nearly three times the evaporation rising from the oceans and seas to that of one from the land.

11. THE WINDS move the clouds over the land and seas, or waters in the same way, and in quantities equal to the difference in the area of land and water, the land receiving as much more water than that which it gives off in vapor, as its area is less than that of the water surface.

12. There is but little to vary or check the wind and cloud in their movements over the oceans and seas, while there are on land mountain ranges and peaks so high and cold that clouds never kiss their summits—while just below these extremes all vapor may be left in ice and snow.

THE NATURAL WATER SUPPLY.

SEC. 3.—1. All the water now upon the land and all in and on the earth has come to it at first by precipitation; and this precipitation must have been EQUAL to ALL the pure water contained in all the ponds, lakes, running streams, snows, ice, glaciers, and neves, and

all in the soil, sands and underflows and reservoirs in the earth.

2. And it will not be easy to controvert the statement of Judge Emery, that "the Almighty does send rain enough from Heaven, if we will take care of it, to raise a crop all over the country from the Missouri River to the Pacific coast."

3. "In the matter of *rainfall*, data obtained from official publications show that the (great plains) regions under consideration embraced between the 97° and 104° meridians, receive an annual precipitation of 18.84 inches. This average is doubtless more than that maintained through the whole area."

4. "In 1889, it was reported of this region by General Greely, chief of the United States signal office, that an annual rainfall of fifteen inches, if properly distributed, is sufficient for successful agriculture upon certain lines without the aid of irrigation. Seventy-five per cent of this fall of rain comes between April 1st and October 1st, which is equal to $14\frac{16}{100}$ inches during the growing season, and gives an annual average of $28\frac{32}{100}$ inches."—(*Judge Gregory of Kan.*)

Rainfall in Northwest Nebraska is 13 inches, in Southeast Nebraska 32 inches, in Louisiana 62 inches.

WATER STORAGE FOR THE PLAINS.

SEC. 4.—1. Under this title in the *Fremont Tribune* of May 11, 1894, "It is stated that *a system of irrigation* comprises artificial lakes, reservoirs, dams and ponds."

2. "A Kansas authority on the subject of IRRIGATION for the plains, has the following to say in the *Irrigation Farmer.*"

"Our water supplies are of four kinds.

1st, The running waters in the rivers and streams.

2d, The underflow waters of the valleys.

3d, The sheet waters in the plains grit, and lastly,

4th, The storm or surplus waters."

3. All these sources of natural water supply can be and should be utilized by first capturing and turning them into reservoirs and storing them for irrigation, during the growing seasons of crops, in cases when and where they are not held and stored in natural reservoirs. Of these natural reservoirs there are three general systems. 1st, The snow and ice in heights above the perpetual frost line. 2d, The ponds and basins, filled as lakes, above the land to be irrigated, but where they remain unfrozen during the crop growing season.

4. The under-flow of stored waters in porous strata forming bends, basins, and reservoirs, which may be reached and brought to the surface by means of artesian wells, pumps, pipings, basin excavations and ditches, and by underground tunnels, or by one or more of these methods combined.

THE HIGH MOUNTAIN PERPETUAL SNOW.

SEC. 5.—1. "In Oregon there is an annual rainfall of 40 inches. It comes in the winter mostly and must be stored in the soil," or in the snow and ice among the mountains, "for summer use when it is needed for irrigation."—(*D. H. Stearns*, *Portland*, *Ore.*)

2. Let us accept the foregoing facts as given by those whose opportunities, observations, scientific training and general knowledge have been such as to qualify them to speak with authority.

3. We then must admit that taking all the precipitation which annually falls upon the 542,000,000 acres of arid and semi-arid lands within the United States, and upon and among the perpetually snow capped mountains and on the plains below these, but above the arid lands, is sufficient to irrigate all the good soil of these millions of acres.

4. All these waters may be utilized for irrigation by means and methods familiarly known to the expert irrigation engineer.

THE RUNING WATERS.

Sec. 6.—1. As we have already observed, all the many streams of running waters have their origin in the natural precipitation, which falling in rain or as snow and hail, melt and beginning to run into some porous stratum, to form underflow, or the source of springs, and little rills, brooks, creeks and rivers of little and of great flows of water, as one after another of the smaller unite and flow on to the ocean.

2. In the spring and summer seasons, the mountain snows and ice attacked by the strong and vertical sun's rays, sometimes melt very rapidly and cause great floods; so, also do great and unusual rainfalls and waterspouts. At such times and localities the running streams rise, overflow their bank, and a very great part of the waters of the annual precipitation is lost, which with wing and catch-dams, ditches, canals, and reservoirs might be saved and stored, to be utilized for irrigation, in addition to all the ordinary flows of these running streams, and the waters naturally stored in lakes and pools, by a method well known to irrigation engineers.

UNDERFLOW AND SUBTERRANEAN WATERS.

Sec. 7.—1. In nearly all parts of the great plain regions where irrigation is most needed, there will be found at a depth of from three to three hundred feet, more or less, below the surface, the water bearing stratum, and in the middle or near the base of the geological cenezoic system, a stratum of coarse sand, gravel, cobble stones or pebbles, small bowlders or larger bowlders, as one passes from the Missouri and gradually rising across the plains and then up into the higher canons and basins in the mountains. This stratum will be found the finest at the Missouri and the Mississippi rivers and increasing in its coarseness in the order above stated, except in certain depressions where

cenezoic waters stood, or the lower cenezoic beds have been covered by psychozoic beds.

2. The statement "that the creative genius of man will be able to find means and methods to utilize this great underflow for irrigation." In speaking of this great water-bearing stratum, Judge Gregory calls it:

3. "AN IMMENSE RESERVOIR," and says "that it has a depth in one place where tested by a well sunk 320 feet and the sheet of water there has been traced out to a breadth exceeding one hundred miles. And similar accumulations in varied quantities have been noted at other points."

CHAPTER VII.

These great sources of water supply may be utilized by many known methods.

FIRST.

BY TUNNELING INTO THE MOUNTAIN SLOPES.

SECTION 1.—1. "The tunnels for irrigation in California were dug under the streams, and also under the Cienega lands scattered along the slopes of the valleys near the mountains, in search of other and greater underflow waters, and these plans were more or less successful, but still more water was needed."—(*Joseph Jarvis, Riverside, Cal.*)

2. And more water might have been found by well directed operations by an expert geologist.

SECOND.

BY SUBTERRANEAN PIPING AND AQUEDUCTS.

SEC. 2.—1. Where the underflow stratum is covered by consolidated rocks, an aqueduct may be excavated from the water supply to the upper margin of the land to be irrigated having a fall from the point of supply to the fields to be irrigated of not less than

about one foot per mile, and of sufficient size and flow to furnish the requisite amount of water to fully irrigate the land at all times when needed.

2. An open ditch or canal will answer the same purpose, where ever it may be most economical.

3. But in many cases where the water must be carried through and upon sandy and porous soil from the natural or artificial reservoir, to the land to be irrigated it may often be found most economical to conduct the water through hard burned clay piping, such as vitrified sewer pipe.

4. Such sewer pipes are in use for conducting water one and one-half miles, from a *natural reservoir* in the form of a pond or small lake to, and through the system of sewerage adopted in this city of Fremont, Nebraska, and it furnishes an abundance and continuous flow of water for this purpose. The lake is a small pond in the valley of the Platte River, and it has no apparent inlet, but it is kept filled by the natural underflow into it, at the same time giving sufficient out-flow for the above purposes.

WATER SUPPLY, HEAD AND SIZE OF CANALS.

SEC. 3—1. The grade and fall of the bottoms of natural running streams are so variable that it will always be necessary for the irrigation engineer to first determine the volume and velocity of the water current to know the capacity of the stream for the needed supply.

2. The more rapid the current of a stream, with any given sectional area of the flowing water, the greater will be the quantity of water delivered within a given time, or per second, as it is usually stated.

SEC. 4.—1. HAVING A SUFFICIENT KNOWN SUPPLY of water in reserve to draw from, the grade being *first* determined, over which a ditch or canal must pass from the source of supply, to the highest margin of the land to be irrigated, and the number of acres, and the num-

ber of inches per acre to be applied at given intermitting periods, for the growing seasons of the crops to be irrigated; the expert irrigation engineer is prepared to calculate and estimate and determine the width and depths of the canal that will deliver a sufficient quantity of water, as it may be required for full irrigation of the land.

2. The volume of water that any given size of canal will deliver, will depend upon, not only the number of feet which it shall fall per mile, but also the fact that a large and deep flow of water over the same grade and kind of material, of the bottoms and slopes of the canal, will be greater in proportion to the size of the area of the section of the flow than it will be in a smaller canal, because of the greater proportional friction on the slopes and bottom of the smaller canal than that on the wider and deeper water in the larger canal. The excess of proportional friction impedes the velocity of the current more in the small canal and ditch than in the larger.

3. Hence the irrigation engineer will, in his estimates, make the necessary allowance for the usual friction of the currents on the slopes and bottoms of ditches and canals, as well as upon aqueducts and pipings.

CHAPTER VIII.

IRRIGATION ENGINEERING.

WASTE WEIRS.

SECTION 1.—1. FROM ALL RESERVOIRS, wing-dams, and other dams, ditches and canals, WHEREVER it is probable or possible that the inflowing waters may at any time exceed the discharge, so as to overflow the embankments, there must be constructed at points

where the water overflow may discharge itself without injury to the embankment, WASTE-WEIRS in sufficient numbers and of sufficient width and depth to discharge all surplus water from the system.

EXPLORATIONS FOR A WATER SUPPLY.

SEC. 2.—1. None but expert irrigation or civil engineers should be employed in the location and construction of any large system of irrigation.

2. THERE IS AN AMERICAN SOCIETY OF IRRIGATION ENGINEERS, which in 1893 was officered as follows: James D. Schuyler, Chairman, of California; Fred L. Alles, Secretary, Cal.; J. W. Gregory, Assistant Secretary, Garden City, Kan.; L. A. Hicks, Assistant Secretary, Yuma, Ariz.

3. In any county in this country having an expert civil engineer and county surveyor, where irrigation works may be needed, these may be safely employed to locate and oversee the construction of a system, if he has this little work and studies and observes its suggestions.

4. But to utilize all the arid and semi-arid lands in the United States or in any other country, there should be a chief engineer in charge, at the capital city, to so direct and supervise a general system, that all the water supply passing from one state to another might never be so diverted, controlled or wasted, that it would not be used to irrigate every acre that it could possibly be made to irrigate.

5. And this chief engineer should, under provisions of law and standing rules, be empowered and directed to see that each owner and occupant of any acre of land to be irrigated, should not be deprived of his just and equitable share of the water of the system of irrigation from which he was at the time entitled to draw the water.

THE LOCAL WATER SUPPLY.

SEC. 4.—1. To establish any local system of irriga-

tion, to irrigate a farm or region of arid lands, the *first problem* for the irrigation engineer is to discover the nearest and most accessible and available water supply, in sufficient quantities for the proposed system, when such water supply has been found:

2. *The second* problem will be to determine upon one of the various methods known to irrigation engineers to reach, secure, divert and conduct the water from its natural course to the land to be irrigated. The irrigation engineer finds that history, experience and observation have given him many practical object lessons in the science of irrigation.

Sec. 5.—1. "Great streams, the recovery of vast quantities of Phieatic waters, the construction of myriads of ditches, canals, locks, dams, aqueducts, tunnels, pumps, pipings, tanks, reservoirs and artesian wells.

2. All these, or at least one or more of them will require the careful and considerate skill of the practical irrigation engineer, the geological stratagraphist and chemist to discover the best and most economic methods and effective application of the water, manures and materials in each, to obtain the very best results, which may include the use of artesian flows of water," gas, petroleum and even coal discovered in drilling deep wells, "as powers for pumping and raising underflow water, and generating electric forces."—(*Gregory.*)

3. Even sunlight and heat has been proposed as a force and power for pumping and an engine has been invented and put into use by Dr. C. W. Allingham, of California, which he thinks may be sufficient to pump irrigation water by the sun's light and heat.

THE ANNUAL PRECIPITATION AS A SUPPLY.

Sec. 6.—1. The irrigation engineer must know or measure the annual precipitation which may fall upon the higher water-sheds from which it may be collected into reservoirs and there stored, far enough above the lands to be irrigated, during the crop growing season,

so that the water then may be conducted by ditches or otherwise, upon the land proposed to be irrigated.

SEC. 7.—1. *The Geologist* must determine the probabilities of obtaining underflow water, and of discovering artesian water; and the *Chemist* must determine the chemical composition of artesian flows, and waters to be used upon soil to be irrigated; which the chemist must also analyze, so that the kind of fertilizer most needed to enrich the soil, as food for the plants proposed to be grown on the land, to get the best results, may be determined upon.

DAM AND BASIN METHODS.

SEC. 8.—1. D. H. Stearns, of Portland, Oregon, has said, "That all that is necessary in Oregon is to run a 'stop' around the head of and near a 'draw' which carries away a considerable quantity of storm water, being careful not to wholly enclose the channel of the supply draw, and then run a short ditch from the stop dam to the upper side of the field to be irrigated. That side will need no 'stop' unless there is a higher level to be covered.

2. Then watch the water that it does not rise high enough to overflow and break the stop before it is turned back into its natural channel. I have seen thousands of places in the valleys of the Platte, Loup, and Elkhorn rivers, where acres could be irrigated fully for a single crop, in this way, at an expense of ten cents per acre.

3. With the ravines in Nebraska and the surplus amount of storm water, they could carry off, there is no necessity for other reservoirs for the cultivation of the soil."

THE BASIN METHODS.

SEC. 9.—1. The water supply may come from the head of a ravine dammed, or from a running stream through a wing-dam or other forms of basins.

2. L. M. Woodbridge, delegate in the International

Irrigation Congress at Los Angeles, 1893, said that:

First: "In basins for orchard irrigation, the whole ground should be covered by a double furrow running down between every alternate row of trees large enough to carry fifteen to fifty inches of water taken from the head ditch, and by the attendant farmer caused to fill basin after basin between the rows until the work of the day is completed. He then repeats the same operation between the other alternate rows of trees.

3. Second: *A Second Method*, by which the water is run into the *first basin* until it is filled, when a portion of its lower side is broken down, so as to let the water fill the *next basin*, and so on until the work of the day has been completed.

4. Third: When only one part of the land is to be irrigated, the basins will only be made within such part.

5. Fourth: *A Modern Method* consists in having the head ditches at the highest side of the (field or) orchard, and running the water down through small furrows to the lower end of the rows or side of the grounds to be irrigated; this is an easy and convenient method," and for various crops.

GRADES FOR IRRIGATION DITCHES.

Sec. 10.—1. To locate, and grade irrigation ditches and canals will require the most careful and best efforts of the expert irrigation engineer, so as to safely lead the water from its natural supply at the head of the ditch to the grounds to be irrigated.

2. The grade must be regularly maintained and made not to fall much less than at the rate of one foot per mile, but it may fall more rapidly where the head is of sufficient heights, provided the ditch passes through materials well consolidated, or if it be made of solid masonry.

3. In extending the length of a ditch or canal for

several miles, it will generally be found most economical to locate it so that its grade will be found meandering along the slopes of bluffs, hills or mountains. And in such cases, any material defect of grade might prove fatal to the utility of that whole system.

4. To obtain such accurate grade may require the aqueduct to pass through, under, and over, rivers, and divides, canons and currents, by means of tunnels, culverts, building aqueducts, sometimes made of solid masonry. will require a most careful and expert engineer.

IRRIGATION IN EAST INDIA.

SECTION 11.—1. The most substantial structures and methods have been in use in India and Asia for thousands of years to irrigate arid wastes.

2. "THE SOLANI AQUEDUCT of the Ganges Canal is 750 feet in length, carried upon fifteen arches of solid masonry, and with approaches 900 feet long. The foundations are 250 feet wide, sunk 20 feet below the bottom of the river.

3. The width of the water channel, carried upon these massive foundations and arches, are 164 feet between the inner faces of the walls, and the water passing through ten feet deep. The Ganges branch canals have each over 3,000 miles in length."

"THE PUTRI TORRENT."

4. "The Putri Torrent is a canal with a fall of 25 feet per mile, and is carried on a superpassage 296 feet wide, about 14 feet deep and near 450 feet long.

5. Along this canal the waters are hurled in waves from three to four feet high, lashing the sides of its staunch walls, which hold them secure in their mad race.

6. And the training works leading this water torrent to the superpassage, are similar massive and costly structures."

7. These irrigation works are characteristic of many

others for like purposes, of India's English public works.

8. *These artificial water channels* of the *Great Torrent*, are constructed to carry a current 200 feet wide and ten feet deep, *both above and below* the surface in the canal, by *aqueducts*, some times *over*, *then under and through other torrents.*"

NARORA.

9. Another great India public irrigation work are the weirs diverting the waters from the *Ganges at Narora.* This weir is 3,800 feet long, resting upon a *concrete floor* 3 *feet thick*, carried on a block of *368 wells* sunk from 20 to 32 feet *below* the *bed* of the *river*. *Its crest* is 6½ feet feet below water level; but the head can be raised 10 feet higher by means of *shutters*.

10. There are *30 openings 7 feet wide* in the *off-lake*, and *42 sluices 7½ feet wide* on the *left side*.

SECTION 12.—1. *The maximum capacity* of the canal in the first *26 miles*, is about *5,100 cubic feet per second.*

2. *The width 216 feet*, and the *depth 10 feet;* "The *extraordinary solidity* of the *Dams* and *Aqueducts* in *India* will be *appreciated* when it is made known to what *extent the rivers sometimes are flooded.*

THE ERRITI.

3. This river has varied from *low* to *high-water* marks more than *50 feet*, flooding houses and villages. *And in 1881 discharging 220,000 cubic feet of water per second.*

SECTION 13.—1. IMMENSE floods come down the Great river in June and July; and if it will not PAY to *make reservoirs* and *canals to conduct* and *store* ALL the *water* of such *great floods*, then provisions must be made in the way of waste-weirs to pass on the surplus waters safely.

2. But it is plain that no private enterprise could attempt such gigantic irrigation works.

SECTION 14.—1. THE HEADWORKS of irrigation canals in INDIA are generally located at the HIGHEST *possible point* of the water supply, and continued as *far* as *possible* along the *highest* divides and slopes permissible by the local topography."—*Extract from a Paper by Geo. Anderson*, M. C. E. of London, and Chief Engineer, Malabar District, *India*, and *Delegate* to the *International Irrigation Congress, at Los Angeles, Cal., Oct. 10th, 1893.*

WATER DISTRIBUTION ON LAND.

SECTION 15.—1. The irrigator having discovered and secured a sufficient water supply for a given irrigation district, he will adopt and construct such a system of connections and distribution of the water upon the land to be irrigated as science, experience and practice shall have pointed out, as most economical and profitable. Among the many varied systems let us note some in use.

FIRST: Tank systems; these are formed of wood, iron, earth and rock.

THE GREAT INDIA TANK SYSTEM.

SECTION 16.—1. *This tank system* is a most important factor in the irrigation of the arid lands of *India.*

2. By this system private parties engage in the forming of reservoirs by embankments, in lengths of from 80 rods to one, two and even three miles long; with an inner slope of 1 to 3, to hold water from 6 to 10 feet deep at the toe and deepest part of the dam; and sufficient to irrigate one crop.

3. *Evaporation* in some locations in *India* carries off from 50 to 70 inches; to prevent this *Lotus plants* with broad floating leaves are planted," as in this country water lillies might be used.

4. One such TANK IN PUNIARI *30 miles long*, another *in Veranum 12 miles long* and its waters covering *36 square miles* and yielding *the proprietors* an *annual revenue of $55,000.*

5. The *larger and deeper* tank (or dam) *where from 30 to 50 feet high*, is made of earth, *but* the *inner* slopes are formed with STONE revetting and sloping from $22\frac{1}{2}°$ to $45°$ degrees from water level.

SECTION 17.—1. IN THE PROVINCE OF THE MADRAS PRESIDENCY there are 60,000 of these tanks, dams or reservoirs of various sizes.

2. They, (like the Johnstown dam) are considered *dangerous* where they *too often occur* along any small ravine."

3. Mr. Anderson, the authority for the above, further says: "That he once investigated a catchment basin containing 350 shallow tanks within a space of 110 square miles."

4. "*The Muduk Tank* which was built in the 15th century, A. D. covered 40 *square miles*, and was 110 feet high at the point where the dam or tank crossed the ravine bottom, with the base of the tank 1000 feet thick.

5. *An-Maisure Tank* is 117 feet high, 225 feet long at the base and only 375 feet wide or thick at the base.

6. The slopes of this country containing these tanks, are from 10 to 20 feet fall per mile, and from this the grade rising at a rate of from 60 to 80 feet per mile.

7. THE MEDIUM CLASS OF DAMS have varied heights and batter from 18 feet in breadth at base, to 12 feet at the top, and down to 60 feet at base, the inner slopes are revetted with rough stone, declining as 2 to 1 away. The revetting from $1\frac{1}{2}$ to 5 feet thick; the vents are 3 x 3 feet, and the waste-weirs from 30 to 120 feet wide, as were shown in sections.

8. *The vent shapes* varied as barrel shapes or as polygons and rectangular holes. These vents or waste-weirs lead off from the lowest points in the tanks."

THE INLET SYSTEM.

SEC. 18.—1. There are different systems for passing the supply waters within the embankments of canals and dams. THE INLET may be a passage through the embankment, or a flume at the source of supply. The gate or inlet may be three feet high or six feet square, and with the outlets, having plug-holes and gibbed stone plugs to close these orifices, having also escape-weirs of from one to four for each tank of 30 to 300 feet wide made of the largest stones used about the dam, and to carry water from three to nine feet deep.

2. DAM STONES, so called, three to four feet high, are used to dam the water so as to give about two feet deeper water.

3. WING-DAM WALLS of from three to six feet high for covering and afterwards diverging the water from tail races and waste weirs, over horizontal or sloping bottoms for long distances.

4. *A lower stone wall* is sometimes placed across the tail, but at some considerable distance from the dam, to intercept some of the escape water which is, or may be taken off by a channel.

5. *In the India Madras* it has been estimated that there are 30,000 miles of tank embankment, and over 300,000 separate masonry works used for irrigation purposes, which yield to the provincial government $7,250,000 per annum in revenue."—(*George Anderson, Delegate I. I. C., Los Angeles, 1893, and India's Irrigation Engineer.*)

CHAPTER IX.

MANY OLD AND NEW IRRIGATION METHODS.

SECTION 1.—1. Both old and new irrigation methods have been successfully tried and used in the United

States in many localities along the Pacific slope, in the arid and semi-arid regions of the great plains, among the peaks and slopes of the mountains.

2. *Mayor Dillon*, of Sheridan, has asked, "What better proof does anyone want that will silence skeptics, than that Sheridan wheat, raised under irrigation ditches took *first* premium at the World's Fair over all competition? Irrigation is a great success in Wyoming, and we have set the pace."

3. *Mr. L. I. Simmons*, of Harrison, Nebraska, President of the Northwestern Nebraska Irrigation Association said, "Wherever irrigation has been tried in our country, it has increased the products.

4. A man who puts even a few acres under ditch is sure of a living. One friend of mine who has THREE acres under ditch, got a yield of $500 an acre last year" (in 1893.)

"ACRE FARMING."

SEC. 2.—1. In a letter from *Chinkiang*, *China*, dated May, 1894, FRANK G. CARPENTER, says: "A large part of the farming of this region is done by irrigation, and the water rights of the *Chinese* are as full of *complications* as those of *Colorado*—still it is wonderful how well they work, and how much they get off the land. *Three crops a year* is by no means *uncommon*. There *are thousands of holdings in China which are less than an acre*, and some are even as small as the tenth of an acre. It is estimated that an *acre* of *land* will, in the better parts of the Empire, *support a family of six*, and a volume could be written on Chinese agriculture.

2. The use of fertilizers is universal; everything is saved and sold for fertilizing," etc.

"In the 8th century, the Chinese engineer Kublal Hahn, laid out and superintended the building of the *Grand Canal over* 1000 *miles long*, which crosses the *Yangtse Chinkiang*.

3. MATT DOUGLAS, of Ogalalla, Neb., has said that "In our valley we have got the water flow in sufficient quantity to irrigate the entire Platte Valley from the Wyoming line to the confluence of the South and North branches of the Platte river.

4. There are now in Scotts Bluff county 450 miles of irrigation ditches, and in Cheyenne county there are over 200 miles of ditches. The test has proven marvelous.

5. THE BELMONT ditch is over twenty miles in length, and it irrigates over 15,000 acres, and has always proved successful since the day it was placed in operation."

6. A. L. KING, of Hitchcock county, Neb., has said: "that the Culbertson irrigation canal recently built from Palisades to Culbertson will be twenty-seven miles in length when the extension to Blockwood creek is complete.

7. It irrigates 36,000 acres, and has a flow of 300 cubic feet per second. It has ten flumes, of which one is a quarter of a mile in length; these flumes are twenty-eight feet high, and the canal works successfully."

IRRIGATION IN CUSTER.

8. Omaha World-Herald, January 26, 1895.—"The Lillian precinct irrigation ditch on the south side of the Middle Loup river, when completed, will be twenty-five miles long, sixteen feet wide on the bottom and will water 11,000 acres. It was commenced September 28, 1894, and nine miles have been completed. Over 100,000 yards of earth have been moved to date, and over fifty teams are now at work.

9. The Middle Loup irrigation ditch on the north side of Middle Loup river, when completed, will be forty miles long and will water 30,000 acres of land. It is twenty-four feet wide and four and a half feet deep, has about fifteen miles completed and about seventy-five teams now at work grading.

10. The Lahorn ditch, four miles long, eight feet wide, was commenced in October, 1894, is now finished and water running in it. The latter is taken from Victoria creek, a tributary of the Middle Loup, and will water about 2,000 acres.

11. The McGraw ditch, taken from Victoria creek, is two miles long, was commenced in June, 1894, is six feet wide and was finished in time to water about 5,000 acres before it froze up; it will water about 1,500 acres next summer.

12. In Loup county along the North Loup on the north side of the river is the Newton irrigation canal. It will be, when finished, eighteen miles long, will water 7,000 acres of land, will be fourteen feet on the bottom and four feet deep. They are working a New Era grader and about twenty teams, have five miles finished, and are in a fair way to have their ditch completed by June, 1895. There are about ten or twelve other ditches along the Loup river that are well under way and the farmers are working hard every day trying to get them done for next year's crop."

DAMS AND RESERVOIRS.

SEC. 3.—1. Stops, dams, dikes and reservoirs have been and may be successfully built near the heads of draws and ravines to stop, catch and save all that it is possible to save, of the waters from the higher levels of precipitation, and the melting of mountain snows.

2. THE RUSSIAN GOVERNMENT has under irrigation 200,000 hectare—494,200 acres—the water supply for which comes through artificial canals and reservoirs, at a cost to the land owner of from \$16 to \$37 per hectare —\$2.47 to \$5 per acre. Ditching on the great Amer plains \$1.50 to \$2.50 per acre; cost of pumping plant \$25 to \$200 per acre.

3. "Russia has for irrigation and pisciculture, constructed dams with derivation canals 790 feet long in the Bobja valley, which are 25 feet high, and in other

localities of various heights."—(Count Comodzisky, delegate to International Irrigation Congress, 1893.)

4. "With irrigation and intelligent application of water and cultivation the right amount of water can be had; because the supply of water is always under absolute control by the owner.

5. And there is enough rainfall and enough storage capacity, and enough capital and American energy to furnish a good water right to every acre of arable and irrigable land in this end of (California), and in every other part of the United States, "and the child is now living who will see as many people in arid parts of California, and the other states, as there are acres of arid irrigable and tillable lands."—(Joseph Jarvis, Riverside, Cal.)

WATER SUPPLY FROM WELLS.

Sec. 4.—1. Where the arid and semi-arid tillable land cannot readily be connected by ditch with running streams or lakes; and where such connection may be practicable, it will often be found, that the underflow which may be reached by wells, will afford the most economical water supply in many localities for irrigation.

WATER ELEVATOR.

2. And in nearly every part of the arid and semi arid regions of the great plains; the underflow waters will be found to be abundant for all irrigation purposes; and may be obtained through wells either by windmill, animal, water or electric power pumping machinery; or frequently from spouting artesian wells.

3. Judge Gregory of Kansas, has said that "Within five minutes walk of his own home there lives a man who has for three years last past supported his family of seven persons upon four acres of ground, which he irrigated by means of a pump and windmill, and they lived in a condition of comfort, even luxury, compared

with families living upon a half section of their own land a few miles distant," and he thinks that "the maximum of land to the head of a family should not exceed twenty acres in the irrigation regions."

THE WATER SUPPLY IN THE ARID REGIONS.

SEC. 5.—1. For the purpose of irrigation within the Great Plains regions, where so much arid and semi-arid lands occur, the region does not wholly depend upon the rainfall within these regions. But the water supply may come from the running streams, and largely from the underflows which have their original sources in the higher lands and mountains where there is an estimated precipitation of about forty inches per annum, and that of "the average of annual precipitation upon the plains, nearly 19 inches.

2. Three-fourths of which is in the growing months. In the mountains the precipitation is still greater," as has been shown.—(*Judge Gregory.*)

AMOUNT OF WATER REQUIRED PER ACRE FOR CROPS.

SEC. 6.—1. During the growing season of crops, they require from local rainfall or by irrigation, or from both, from twelve to twenty inches, or as an average about fifteen inches of water, to be applied over each acre in depth, to secure the best results for the three to five first years of irrigation and cultivation.

2. After which, the ground having become saturated with water, it will require much less water to secure good results.

COST OF WATER SUPPLY FOR IRRIGATION.

SEC. 7.—1. It has been found from actual practice, that it costs for irrigation works where constructed by governments as public works, under different difficulties, from three to not exceeding sixteen dollars per acre to irrigate arid lands. This includes the cost where the water has been pumped or carried through safe canals and aqueducts, constructed in many parts

of solid masonry, from ten to one hundred miles, from running streams, lakes, and artificial reservoirs. Hence, no private corporation or person should be allowed to charge more than a rate equal to a low interest and cost of repairs of such irrigation system for water rights.

2. A farmer in Jefferson County, Colorado, has a windmill irrigation plant which cost him $150 and with which he irrigates seven acres of land. It is considered the cheapest water supply that can be had for irrigation purposes.

GREAT PLAINS UNDERFLOW WATER SUPPLY.

SEC. 8.—1. The geologist finds that at the closing upheavals of the Mesozoic Age, the greatest part of North America lying west of the Mississippi River, and that now, known as the Great Plains Region, was lifted out from under the Mesozoic, and later Cenezoic oceans.

2. The Rocky, and other continental mountain regions coming up first and in earlier geological ages, the higher elevations rising fastest; the lower at the same time, rising slower or subsiding.

3. While the waters of the older Mesozoic and later oceans were being emptied and extinguished by being rolled away over the great plains, then very little broken or bent, but receiving, first the coarser and then the finer sediments carried along by the deep and rapidly moving oceans of waters, until these found a resting place in the present lakes, seas, and oceans. The coarse fragmental rocks from the mountains being laid down nearest the mountains, in the more rapid moving waters, and as the waters moved slower and farther away, they laid down finer and finer silts.

4. The result of these movements, was to leave under nearly all the great plains regions, a stratum of bowlders, cobble-stone, pebbles, gravel, coarse and finer sands, which now form a porous and water bear-

ing reservoir. Over this reservoir, near the Missouri and Mississippi rivers, we find the loess deposited, composed of clay, sand and vegetable mould, mostly; while nearer the mountains, clay, sands and volcanic ejectments cover the surface in spots, and of greater or less area.

5. The water stratum over a very large proportion of the whole area of the great plains, may be reached by wells, and drills, within a depth of about five to fifteen feet in the valleys, and within one hundred to four hundred on the table and plateau lands.

6. From this great reservoir in the water bearing stratum, the water in abundance for irrigation may be lifted, pumped, lead by pipings, tunnels and ditches; the latter having a falling grade of not exceeding one foot per mile, will approach the surface of the valley and table lands at a rate of elevation of four to about fifteen feet per mile, more or less, so that such piping and ditches will not have to be continued many miles to take the water from this great underground natural supply reservoir to the surface of lands which it may be desired to irrigate.

ARTESIAN WELLS.

SEC. 9.—1. Besides and below the great underflow stratum mentioned, may be found by deep borings, other water bearing strata, in porous rocks, lying between impervious strata. Wherever a water stratum so confined by impervious layers of rocks can be reached by the driller, there may he almost certainly obtain an artesian flow of water, with greater or less gushing pressure.

2. And "for high table-lands we must often look to artesian water, and should have government assistance, as well as laws that will allow us to take water from streams."—(*L. J. Simmons, Prest. of N.-W. Neb. Irri. Association.*)

3. At the convention in Omaha, March, 1894, of

the Interstate Irrigation Association, on the motion of Mr. Carnahan, of Colorado, it was by the convention, "*Resolved*, that the government should determine by actual test whether or not artesian water can be obtained upon the great plains, and if so, to what extent."

4. Every person who has given the subject careful consideration knows that hundreds of artesian wells are now in successful use for irrigation and other water purposes in California, and thousands of them in other parts of the world.

5. Many an artesian well has been known to send out their waters with such great force as to furnish a direct pressure power sufficient for driving machinery.

6. We notice the following in the Fremont *Daily Herald* of March 30, 1894.

"AN ARTESIAN BOOM."

"The artesian boom is on in South Dakota, and it is now proposed to use well power for storing electricity in accumulators, with which to drive plows and operate reapers, mowers, hay-rakes, threshers and other machinery."

7. Joe Teahor said, Dec. 4, 1894: "When I left Scotland, S. D., yesterday, there was much excitement over an artesian well just struck at a depth of 575 feet, which was sending out an inch stream of sweet, soft and pure water, at the rate of 5,000 barrels a day. Sunday night the flow increased to 11,000 barrels in each twenty-four hours. The people of this town have invested now $25,000 to secure artesian water and are jubilant, as this well will furnish more than enough water for domestic and fire purposes."—(*Omaha Daily World-Herald, April 12, 1894.*)

8. "Albert Jacox, living south of Basset, Rock County, Neb., has a flowing well ninety-five feet deep, which puts out 300 gallons per hour, through a one and one-quarter inch pipe. It is on a small rise, and

he irrigates twenty acres of garden and orchard from it."—(*Fremont Herald, Aug. 8, 1894.*)

OIL STRUCK IN WISCONSIN.

9. "Oil was struck this morning at a depth of 200 feet, by men boring an artesian well on the Weis dairy farm. The flow is large, with a mixture of water.

10. Though the quantity of oil seems to be large, there can be little hope that it will last long enough to be of any commercial value."—(*Omaha World Herald, Feb. 1, 1895.*)

CHAPTER X.

DEEP WELL DRILLING. TO OBTAIN ARTESIAN WATER, GAS AND OIL FLOWS WITHIN THE ARID REGIONS OF THE PLAINS AND PIEDMONT DIVISION OF THE UNITED STATES.

SEC. 1.—1. Many intelligent persons and some geologists, who appear to think that there is little of geological interest or economic value within the vast arid regions of the Plains and Piedmont Division of our country, or within such regions of any country.

2. The fallacious views ought to be dispelled by the organization under the geological survey of a "Plains and Piedmont Division" and a competent geologist placed in charge with a sufficient force, means and directions to make thorough geological survey of not only the surface, outcroppings and minerals naturally exposed; but also by a few deep drillings at such localities as the unbroken and anticlinal and synclinal strata may indicate to be likely to yield most beneficial results. To understand correctly, as to just where these borings should be made the geologist should be pretty thoroughly acquainted with the history and results obtained by deep well drillings.

3. And to lead up to a general knowledge of this subject we will give a summary account of artesian, gas and oil well enterprises, under the general heads of ARTESIAN WELLS; PETROLEUM; GAS AND OIL WELLS.

4. And in these connections we will speak of the valuable results which may be expected to be derived by the people of Nebraska and other states, included within a "Plains and Piedmont Geological Division" when so surveyed. It may be asked:

5. Shall we expect to find silver and gold in these regions in sufficient quantities to pay for mining? We must say; the survey alone will reveal a satisfactory answer. But no conservative geologist will say, that even silver and gold mines of great value would not be discovered; even in Nebraska.

6. But in this essay, we will speak of other valuable minerals which may reasonably be expected to be found here, of quite as much importance to the future prosperity of this great region as even the discovery of silver and gold mines.

7. These discoveries, where not otherwise manifest, will be made so; by artesian and petroleum wells, driven deep into the earth.

That the explorator, who follows this course, according to the best known methods and the experience of the past, will succeed, there can be no doubt.

ARTESIAN WELLS.

SEC. 2.—1. In the valleys, and for ordinary uses, water may usually be had from springs and shallow wells, at depth not much below the surface of the nearest creek, river or lake.

2. But on high table lands and mountain slopes, it is generally necessary to dig or bore for water to considerable, and great depth.

3. These deep borings frequently reach water immediately above the first impervious stratum; but if not found at this horizon, then go through the impervious

stratum, which at a higher level than that of the surface of the ground where the well is located, should be broken; as well as that of a porous stratum, under the impervious roofing stratum, the well-maker will, most likely, find in reaching the porous stratum, artesian waters rushing up to, and above the surface of the ground; in many cases shooting high in the air, as a fountain of water.

4. But the borer will not always find such artesian waters under the first impervious stratum; yet, if the depths be not too great, and all the known stratified rocks have not been passed, the well-driller need not be discouraged, until all these have been passed.

5. Where the waters from rains and snows enter the pcrous stratum at great heights above the surface of the ground at the well, which giving vent to the water, it will sometimes rise with such velocity and force as to be sufficient to drive machinery; and supply farms, towns and large cities with water as good, and usually better, *or* as well as they might have been supplied by long and expensive aqueducts, or by powerful engines.

6. The flow from large wells or from several of these has been found in some cases to be sufficient to irrigate farms and large areas of arid countries, where by *the* once desert wastes have become highly productive and thickly populated, cities built, and now are occupied by peaceful and industrious people.

THE HISTORY OF ARTESIAN WELLS.

Sec. 3.—1. It is said that the Chinese and Egyptians have known how to construct artesian wells for thousands of years; and it is quite probable that they have been used ever since Moses smote the rock in Horeb with his rod and the water came out.

2. But at that time, in the lands now inhabited by the most civilized people, there could have been but little knowledge of artesian wells.

3. The knowledge, through these latter countries, has advanced with better understanding of machinery, tools, and of geology. We have thus been taught to locate artesian wells, on benches, slopes and in valleys.

4. And that artesian water must be obtained from a reservoir under the earth in a porous stratum which may consist of broken rocks of limestone, metamorphized limestone, such as a dolomite, or a porous sandstone, sands, gravels and bowlders.

5. The roof and floor of such water containing reservoirs, may be of any kind of rock which will be impervious to the included water, such as clays, shales, compact and close grained limestones, consolidated sandstones, or other impervious beds and layers of rock.

6. There has been hundreds of artesian wells drilled at Vienna and other parts of Austria.

7. The government geologist of Algeria, in his report of operations in northern Africa for 1856 and 1857, shows that a great many artesian wells have been drilled at different places in the Great Sahara Desert, and in the Provinces of Constantine.

8. And that the artesian waters have there been reached at depths varying from 1000 to 1300 feet.

9. And from a report in 1887, it has further been shown that there was then not less than 75 of these artesian wells in the *Sahara Desert*, from which 600,000 gallons of water flowed every hour.

10. So that where there was but a few years ago nothing but burning sands driven by hot and fierce winds, which compelled the Nomadic tribes of Arabs and their camels to bury their heads in the sand to protect their lives.

11. There now are found about, and from the water-flows of artesian wells, thrifty villages, beautiful green lawns,, delicious growing tropical fruits, and settlements of happy, industrious and civilized Arabian

people, showing that artesian wells have "made the desert bloom and blossom as the rose."

12. As the knowledge, feasibility and great benefits of these wells have become better known, their numbers, and even their greater depths have increased.

13. An artesian well at Pest, drilled 3,100 feet deep, yields 175 gallons per minute or 10,530 gallons per hour, 242,724 gallons per day.

14. The great depth from which the water comes has caused it to rise with the temperature of 161 ° F.

15. An artesian well drilled 4,162 feet deep, at Sprenburg, Prussia, is said to yield a large supply of water which is probably hotter than that at Pest.

16. In 1798 there was one of the earlier of modern artesian wells, drilled 393 feet deep, which yielded 516½ gallons of water per minute, 31,020 per hour, 744,480 per day.

17. Without more specific statement we will say that there are many such artesian wells of depth averaging about 340 feet in the London Basin, England, yielding great quantities of most excellent water, which is found in a reservoir of the upper Mesozoic age rocks.

18. And it is in the rocks of this geological age that artesian water is found at Paris, in France, under the rocks known as drift.

19. Well informed geologists know that in Eastern Nebraska in many places the Mesozoic age rocks may be found immediately under the surface rocks of the Drift period.

20. There have been some deep wells drilled in the United States which will be noticed before closing our history of artesian wells, that the casual observer has become familiar with them.

21. The records of these drillings show that some have been located as high as 1030 feet above sea level, (nearly the level of eastern Nebraska), some of which have been driven to a depth of 1900 feet below sea evel. Others have been driven 2678 feet deep.

22. Crewzot has shown that these deep borings proves that, for all depths below the surface in the the temperate Zones, at the depths of the first 55 feet the temperature of the earth is about 52° F. And that there will be an increase of temperature of one degree for each succeeding 55 feet in depth down to about 1800 feet deep. Below this the heat increases more rapidly so as to make an average at 2678 feet of one degree of heat for every *44* feet in depth, and no doubt that as the depth extends, the rapidity of the increase of the heat will continue.

23. A successful flow of artesian water has been reached at St. Louis at the depth of 3843½ feet. And at Louisville, Ky, a well drilled 2086 feet reached a reservoir of artesian water. An artesian well was found to flow at the depth of 1250 feet at Charleston, S. C.

24. Artesian wells are now common and well-known in Pennsylvania, Ohio, New York, Indiana, Canada, Kansas, South Dakota and Northeastern Nebraska, and along the Pacific slopes.

25. As late as in July 1893 artesian water was found to flow from a drill 800 feet deep, at Belle Fourche, Dakota. In Nebraska artesian water has been found in Boyd, Knox, Dodge and Lancaster counties.

A NEBRASKA ARTESIAN WELL.

26. The artesian well at Niobrara, Neb., of which we give an illustration, has a depth of 650 feet, and is utilized in connection with a system of waterworks, electric light and motor powers, and a large flouring-mill.

27. The well has a flow of twenty-five hundred gallons per minute through an eight-inch pipe, and with a pressure of ninety-five pounds to the square inch, the water rises to an elevation of eighty feet. The spectacle, as the jet shoots upward and breaks and falls in masses of spray, is one of great beauty.

28. The water has a temperature of seventy degrees. The well is owned by the milling company of the enterprising town.—*Nebraska Democrat, August 11, 1894.*

29. In Pennsylvania, West Virginia, New York, Ohio, Canada, Indiana, and more recently, as late as in August 1893, in Illinois and North Dakota, in drilling for artesian water, gas and oil has been discovered.

CHAPTER XI.

PETROLEUM.

SECTION 1.—1. Wells drilled for artesian water may reveal the more valuable products of petroleum in the several forms of NATURAL GAS and MINERAL OILS. And may include the several substances known in science under the following names: 1 Petroleum, 2 Naphtha, 3 Bitumen, 4 Rangoon, 5 Paraffine, 6 Caoutchouc (Koo chook), 7 Caoutchoucine (Koo choo sin), 8 Kerosene, 9 Asphalt. Some of these names are but synonyms of others.

PETROLEUM.

SEC. 2.—1. The word petroleum is formed from the Greek words signifying a rock and oil. So we sometimes say rock oil.

As early as near 2000 B. C. it was said that "When the rock poured out oil for Job (29 ch. 6 v.) he rejoiced."

2. *Naphtha* is a Persian name and signifies an inflammable liquid of Hydro-Carbon. Or perhaps a mixture containing three several Hydro-Carbons.

FIRST—C7, H14, which boils at a temperature of 190° F or 87° C. This form of HC contains no oxygen.

3. SECOND—C8, H16, which boils at a temperature of 239° F or 115° C.

Third—C12, H24, which boils at a temperature of 394° F or 190° C.

Asphalt appears to have several names; or several minerals by some experts are called asphalt which by others are called by different names. Among these may be mentioned Native Pitch, Mineral Pitch, Jew Pitch, Dead Sea Bitumen, Compact Bitumen, Trinidad Bitumen, and Maltha. Perhaps to these should be added Asphaltic Coal.

4. These occur in nature in compact forms of an oily consistency, and in cracks, cavities and crevices of the solid rocks of the lower coal measure, and in the geological *Devonian system.*

5. *Asphalts* of the various kinds have a pitchy odor and a black, dark brown or pitch color, but they do not soil the hands when touched. They are insoluble in water; sparingly soluble in alcohol, but may be dissolved by ether, oil of turpentine and by kerosene.

WEIGHT OF PETROLEUM.

Sec. 3.—1. The weight of petroleum is as 1,100 to that of 1,000 for water. Petroleum burns with a smoky flame. It is found in New Brunswick, West Virginia, Ohio, Kentucky, Indiana, Illinois, the Dakotas, Wyoming and many places along the eastern and Rocky Mountain slopes.

2. *Persian Petroleum* in nature often occurs so nearly pure as to be suitable for burning without refining.

The Burmese Petroleum is called *Rangoon.*

Section 4.—1. Petroleum is abundant along the coasts of the Caspian Sea; and has been found in Burmah, Japan, Siberia, Prussia, Galacia, Roumania, Scotland, France, Italy; and in America, in Canada, New York, New Jersey, Pennsylvania, West Virginia, Ohio, Indiana, Illinois, the Dakotas, Wyoming, Colorado, California. And may be looked for elsewhere.

2. *Petroleum* is said to have been FIRST discovered in America by the Indians who collected it and sold it to white people for medicinal uses.

3. But petroleum as an article of merchandise of great value, and as known in mineralogy, has been largely discovered and obtained through deep drillings from oil wells. In this country petroleum so discovered has been called coal oil, rock oil and MINERAL OIL. Analysis proves it to be a liquid, HYDRO-CARBON.

4. *Bitumen*, has been, by some *mineralogists*, the name applied to the solid petroleum; But by others the name of NAPHTHA has been applied to liquid petroleum.

5. The ancient Romans, under the name of Naphtha, included, Mineral Pitch in several varieties such as Mineral Resin, Asphalt and Mineral Caoutchouc.

6. Both Naphtha and Petroleum, as they are now known, essentially consist of carbon and hydrogen, in parts as of 84 to 88 per cent of carbon; and with about 10 per cent of oxygen, forming solid Asphalt in containing a little Nitrogen.

7. Bitumen is contained in most varieties of Mineral coal, and in some black and some brown shales, slates and marls. And when these contain bitumen they are called bituminous; as bituminous shale.

CHAPTER XII.

HISTORY.

SECTION 1.—1. In 1859, Petroleum wells in the United States, were drilled in Pennsylvania, the first well yielding 82,000 barrels in the year.

2. In 1861 the yield from all known wells in America was 2,000,000 barrels. In 1872 the North American oil wells yielded 7,394,000 barrels.

3. In 1884 the United States exported 24,019,750 barrels of Petroleum.

4. In 1887 the Petroleum industries had so far expanded that as many men were then employed in it as were employed in either the coal or iron industries in North America.

5. *Paraffine* oil is a species of oily matter obtained from the distillation of Boghead Carmel coal. And a residuary substance formed by the refining of mineral petroleum.

6. *Paraffine* may also be obtained from wood, nearly pure, by distillation. This oil boils at a temperature of 111 ° F. or at 44 ° C.

7. But to obtain paraffine from some other substances it has required a temperature of 700 ° F. or at about 371 ° C., to cause it to boil.

8. The French Chemist Berthelot, and the Russian Chemist Nendegeff, by chemical process, extracted petroleum from coal, which was by them called maltha.

ASPHALTUM.

Section 2.—1. In *Asphalt* is a bituminous substance of a more or less plastic or approaching solid form.

2. In nature it sometimes occurs in large bodies and is called "Pitch Cakes," in Trinidad, "Pitch."

3. *Pitch Cakes* occur on the coasts of the Dead Sea, where the Arabs collect it under the name of "Moses Stone."

4. *Asphaltum* occurs in Coxitamb and Cuenca, in Alsace; in Scotland, at Lothiari, Fifeshire, and other points in Continental Europe.

THE NAPTHALIC PETROLEUMS.

Section 3.—1. *Napthalene* contains the elements which for brevity may be shown by the chemical symbols, C10 H8. This substance has much historical and chemical interest.

2. It was on the analysis of Napthalene that the Chemist Lawrent founded his theory of substitution.

3. The *Artificial Formation of Napthalene* is effected by distillation of coal tar, and otherwise, as a semi solid when cold, but by pressure it will flow out as a liquid, taking up the napthalene with hot alcohol, from which it may be obtained in a pure state, as by this practice it crystalizes and sublimates.

SEC. 4.—1. Its crystals are thin rhombic plates. Napthalene crystals form  thus, sides of equal length, unctuous to the touch and with a pure lustre. Napthalene under glass, exposed to the light will sublimate, taking splendid crystal forms at ordinary temperature. It has a tar-like odor and a pungent, somewhat aromatic taste. It will fuse at a temperature of 176° F., 80° C., and it will boil at 424° F., 218° C. Its specific gravity while in a solid state is, as compared with water $\frac{115}{100}$.

2. When ignited it burns with a white and smoky flame. It is insoluble in water, but dissolves readily in alcohol, ether, or in fixed and essential oil.

3. With an excess of sulphuric acid, by chemical action so produced, it changes to a substance called "Sulpho," (C_{10}, H_7, SO_3, $+H_2$, O,) by the action.

4. Several other substances are produced, and with nitric acid, when adding N_5, O. Napthalene yields Nitro Napthalene, C_{12}, H_5, N, O, or their multiples. Substitutions as the equivalents of 1, 2, + 3, by Hydrogen of Napthalene."

5. Through the operations of an analysis the elements called atoms must first be set free from any one chemical compound substance before they can chemically combine to form another and a differently chemically combined substance.

CHAPTER XIII.

THE NATURAL ELEMENTS (ATOMS) OF PETROLEUM.

SECTION 1.—1. In well borings for petroleum, the driller often before reaching oil or water, sets free NATURAL GAS.

2. At first this was peculiarly true in the Ohio, Indiana and contiguous petroleum fields.

3. The natural gas which occurs at different localities, varies as to its purity, and in various relative proportions of its elements.

4. As at Muncie, Anderson, Kokomo and Marion, its elementary weight varies from 0.57 to 0.60, that of Marsh gas.

	MUNCIE	ANDERSON	KOKOMA	MARION
	92.67	93.70	94.16	93.58
Atoms	2.35	1.80	1.41	1.20
Olebrant Gas	.25	.49	.30	.15
C, O.......	.45	.73	.55	.60
C, O......	.25	.26	.29	.30
O.........	.35	.42	.30	.55
N.........	3.53	3.02	2.80	3.42
S, H.......	.45	.15	.18	.20

Natural gases are the gases that are formed in and upon the earth by natural causes, and their chief elements are carbon and hydrogen, and hence they are called carbonated hydrogen.

5. In nature's laboratory, as in that of the practical chemist, each element of one natural compound must be first set free before it can combine differently to form another natural substance.

6. The Findlay gas wells yield a product of which 90 per cent is carbonated hydrogen.

7. Natural gas has been known to have occurred in the lower Silurian, Eozoic aged shale, blue and dove colored dry limestone, where it was composed of;

Carbonate of lime	54.30
Carbonate of Magnesia	33.60
Alumina and Oxide of Iron	3.90
Silicious Residue	6.10
Lost by Evaporation	2.00
Total	100.00

Before the discovery of natural gas by the drilling of deep wells, most of the gas used for lighting private buildings, towns and cities was distilled from mineral coal, leaving a coke and coal tar on its passage from the hot distilling furnace to the gas tank or holder, depositing the coal tar by gravitation in a tank placed so as to receive it from the retorts. The gas passing on as a volatile substance to the purifying tank where it rose through water into the tank.

Sec. 2.—1. The explorators with the drill have shown in Indiana, that there, is the largest known petrolific gas rock field in the world, it containing 1800 square miles.

2. In the Gas Field known in Pennsylvania, Ohio, West Virginia, Indiana, and Canada, the Petrolific rocks have all been found below the Carboniferous aged formation, and in the Stratified rocks of the Aqueous or Invertebrate age; and in the upper portion of that age, or at the base of the Carboniferous, in the so called Trenton; or lower in the Niagara limestone, the Utica and Hudson river shales, and Devonian sandstones.

3. But natural gas in other Petroliferous fields has been found in the newer rocks above, in each sedimentary formation up to those of Psychozoic age. Wherever an impervious rock and natural gas reservoir have occurred, increasing cellular and petroliferous rocks, with evidences of having at some earlier age been sufficiently moist and heated for the natural distilling of the gas, oil, and other bituminous substances.

4. But in Indiana, the surface rocks, where usually

they are of aqueous age, the Petroliferous rocks are those of the upper and middle Silurian age.

PETROLEUM FIELDS.

SEC. 3.—1. Petroleum fields are those regions where mineral oil or rock oil may be obtained from the earth.

2. These oils are now known in the United States as Petroleum, but in some foreign states it is known by the name of Naptha.

3. Where petroleum has been distilled from buried materials by natural processes, it is not very different from that formed by artificial means from wood, exhumes, bog-head, swamps, mineral coals, black sandstones, black shale, black slate, caoutchouc, hevea-gunensis slates. The two last named substances are used in the manufacture of India rubber goods.

4. In speaking of the petroleum fields, we include many gas fields.

5. NATURAL GAS and petroleum, as mineral oil, have been produced, but by a little different cause, from fossilized, animal and vegetable material under a less or greater heat and pressure, with moisture.

6. Where, on the surface of the ground the petroliferous rocks do not crop out and appear, and one has good reason to believe that such rocks exist, at considerable depths, the drill may be used to test the strata down to the granite rocks, below which no oil or gas is found in paying quantities.

SEC. 4.—1. Where the surface rocks are the Archaean granite, Azoic rocks, no petroleum will ever be found in or below these.

2. The evidences of the upheaval of the strata must appear in the petroleum field, and the formation of anticlinals, into this summit of rather flatly formed anticlinals, the explorator must enter his drill to find coal, mineral oil, petroleum in the form of gas, liquid petroleum and solid naptha.

3. The anticlinal may be an unbroken fold, a table land or a bench.

4. But there must be found in it a natural reservoir below; the summit surface having an impervious roof, usually of clay, shale, slate or any other impervious rock.

5. Under the roof there must be found a porous rock which may contain gas, oil or water.

6. The elements of petroleum must have been distilled from a petroliferous formation probably below the gas or oil reservoir, and may have as the lighter fluid flowed up, or have been by water forced up into the reservoir; so as to have provided sufficient pressure to form a gushing gas or oil well, or to make an artesian well when pierced by the drill.

7. Sand, gravel and bowlder beds have the natural porosity to form such reservoirs; and that "porosity is found in a very high condition in crystalized dolomitic limestones; in which there is found sufficient space in the interstice of the small crystals forming the dolomite to contain the petroleum deposits."

8. In the Indiana oil fields the gas and oil are reached by the drill wherever it pierces the marbleized limestones; dolomite called there the Trenton limestone.

9. In Canada it was thought that only the Devonian rocks and older and lower rocks were petroliferous, and that gas and oil had been distilled from rocks lower than the Devonian roof of the reservoir.

10. While in Pennsylvania it was believed to have come from the higher and newer carboniferous beds. But in both Canada and in Pennsylvania the petroleum was found in a porous sandstone reservoir of Devonian geological period.

11. But it is now or may be generally conceded that petroleum may occur in the rocks of any geological age; have a porous reservoir with an impervious roof, under which beds of fossils are buried.

SECTION 5.—1. The gas and oil rocks at Findlay, Lima and Bowling Green, Ohio, and at Muncie to Kokomo in the great gas and oil fields of Indiana, is the Trenton limestone, where it has been through internal heat changed to a dolomite. This rock at Muncie and Kokomo contains these several elements:

2.	MUNCIE.	KOKOMO.
Carbonate of lime	51.96	52.80
Carbonate of Magnesia	38.11	39.50
Alumina and Oxide of Iron	3.72	2.40
Silicious Residue	3.30	4.60
Lost by Evaporation	2.91	.70
	100.	100.

3. So at most of the very great number of deep drilling in the great petroleum fields it is found that the dolomitic reservoir of each severally varies in its elementary composition.

4. Limestones containing from 80 to 90 per cent of carbonate lime are too close grained, and want the porosity necessary for a petroleum reservoir.

CHAPTER XIV.

SECTION 1.—1. Where the geological ages are named from the conditions and kinds of their rocks and from their several characteristic contained fossil life forms.

2. FIRST—Geological age must be called the Igneous and the Azoic Age.

SECOND—The Aqueous, Molluskan and Invertebrate Age.

THIRD—First Age of Lowlands and Vertebrates.

FOURTH—The Hill, High and Valley Lands, Reptillian Age.

FIFTH—The Leveling and Mammalian Age.

SIXTH—The Finishing, and the Age of Man.

3. But a briefer and more convenient designation

of these geological ages, if we may allowed to include the whole period of the time of what many geologists include in the so-called "Cambrian Lower, Middle and Upper Silurian," during which periods there was no vertebrate, no land life, while all life was marine. Aqueous and all animals were invertebrate, in the Second Age. To name the ages with reference to the progress of life.

SECTION 2.—1. We should call the

FIRST—The Azoic Age.

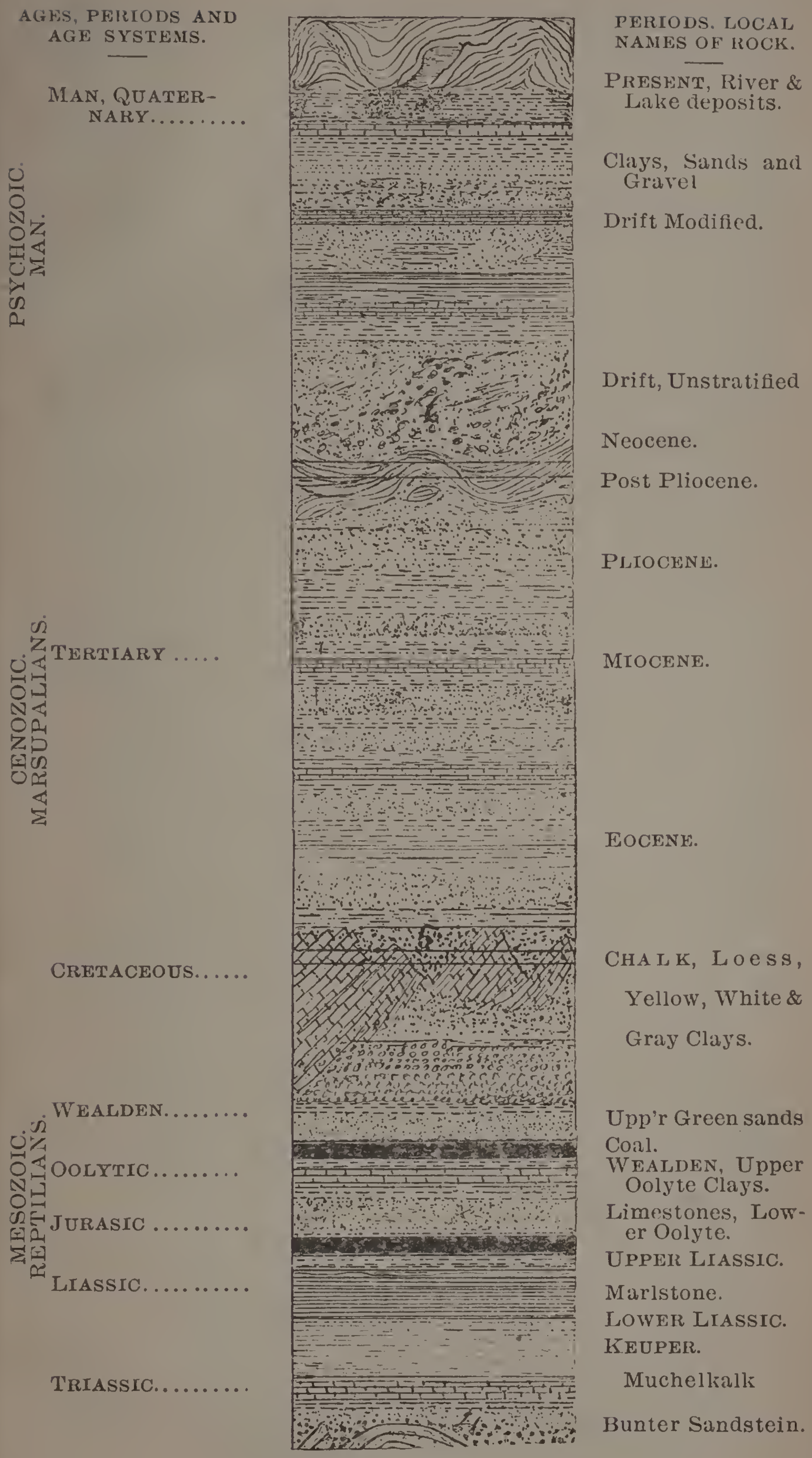
SECOND—The Eozoic Age.

THIRD—The Paleozoic Age.

FOURTH—The Mesozoic Age.

FIFTH—The Cenozoic Age.

SIXTH—The Psychozoic Age.


AGES, PERIODS AND AGE SYSTEMS.
PERIODS. LOCAL NAMES OF ROCK.
PSYCHOZOIC. MAN.
MAN, QUATERNARY..........
CENOZOIC. MARSUPALIANS.
TERTIARY .....
CRETACEOUS......
MESOZOIC. REPTILIANS.
WEALDEN.........
OOLYTIC.........
JURASIC ....
LIASSIC...........
TRIASSIC..........
PRESENT, River & Lake deposits.
Clays, Sands and Gravel
Drift Modified.
Drift, Unstratified
Neocene.
Post Pliocene.
PLIOCENE.
MIOCENE.
EOCENE.
CHALK, Loess, Yellow, White & Gray Clays.
Upp'r Green sands
Coal.
WEALDEN, Upper Oolyte Clays.
Limestones, Lower Oolyte.
UPPER LIASSIC.
Marlstone.
LOWER LIASSIC.
KEUPER.
Muchelkalk
Bunter Sandstein.

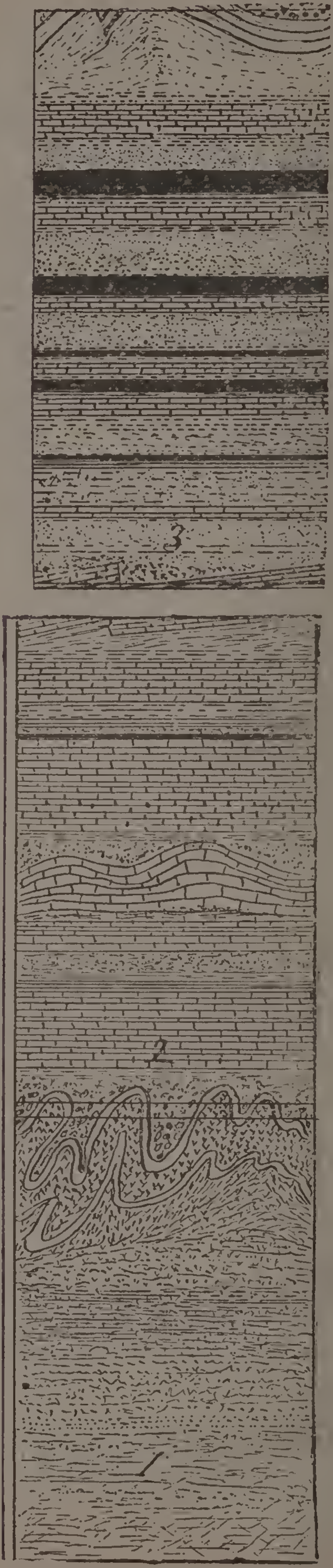
AGES, PERIODS AND AGE SYSTEMS.

PALEOZOIC. AMPHIBIANS.
PERMIAN.... ....
CARBONIFEROUS..

FISHES.
Catskill..........
Chemong.........
Subcarboniferous.
Hamilton.........
Carniferous.......
DEVONIAN........

EOZOIC. MOLLUSCAN INVERTEBRATE.
Oriskana..........
Lower Helderberg
Salina.............
Niagara...........
Clinton.......... ....
Medina..... ......
Cincinnati.........
Utica..............
Trenton ....
Canadian..........
Primordial........
Cambrian ....

AZOIC. IGNEOUS.
Archæan.........
Igneous. ....
Granite Bottom...



PERIODS, LOCAL NAMES OF ROCK.

PERMAIN.
Upper Coal measure.
Limestone.
UPPER COAL.
Limestone.
Sandstone.
Lower Coal Meas.
Limestone.
Sandstone.
Coal.
Limestone & Sand
Coal.
Catskill, Chemong
Portage.
Genesee Shale.
Hamilton, Marcellus, Schoharie.
Corniferous.
Canda-Gallic.
ORISKANA LOWER
Helderberg, Salina
Niagara, Clinton.
Medina.
Cincinnati.
Utica.
TRENTON.
Chaza.
QUEBEC.
Calciferous.
Potsdam.
Arcadian.
Archæan.
Neiss
Granite.

THE ROCKY FORMATIONS.

4. The rocks of the "First Geological Age" being the lowest known and the oldest; and the rocks of each succeeding age being higher and newer than those of the rocks of the earlier geological ages.

SEC. 4.—1. The petroliferous rocks of Pennsylvania, Canada and Indiana have all been found to belong to rock capped or covered by the upper carboniferous paleozoic beds, and the petroleum deposits in or under the so-called Devonian beds which cap the Eozoic Age beds. And the Devonian may be said to lay at the base of the lower carboniferous Paleozoic Age rocks.

2. The petroliferous rocks in Ohio and Indiana are the the middle and Silurian of the Eozoic Age.

Where a well was drilled at Logansport, Indiana, the surface rocks are called the Lower Helderberg; these are below the Devonian, consisting of a water limestone, a silicious limestone of a yellowish color, and 15 feet thick. Next below this surface rock there is an 8 feet thick blue limestone. Then lower the 3d 20 feet of fire limestone.

3. A second well which beginning below surface colored Devonian limestone; the drill passed down through the Lower Helderberg from the top. 1st, A brecciated chertry layer 15 feet. 2d, Fossiliferous and evenly bedded magnesian limestone, 15 feet. 3d, Thin bedded water limestone, 10 feet. 4th, Thicker impure water limestone bedding, 15 feet. 5th, Thin bedded water limestone, 10 feet. Total 65 feet where gas was first reached by the drill.

4. The thickness of these several beddings appear to have been the results of volcanic heat and flow from

the more or less powerful pulsations of intermittent volcanic eruptions and heat under the sea.

5. But continuing the borings down to the Trenton beds, that is below the middle Silurian Eozoic Age rocks, wells in Indiana have reached at the several depths from 800 to 1,600 feet, gas and oil. And reaching horizons from 100 to 300 feet below the sea level, from where the gas and oil were forced up by salt water pressure, which sometimes when the oil stratum had by the drill been passed gave the proprietor an artesian well of salt, or fresh water having great force.

6. When the surface rocks are lower Helderberg, through which the drill first passes and all the following beds, if found, down to the Trenton (upper part of the lower Silurian) beds, Eozoic Age system of limestones which are the Indiana oil bearing, or the petroliferous reservoir, then from the surface pass through several strata below in the following order of beds: The Salina, Niagara, Clinton, Medina, Cincinnati and Utica, and then entering the Trenton a few feet the drill reaches and sets free gas and oil from this limestone or Dolomite reservoir.

7. But we must not forget that in most localities some one or more of the strata named will be missing. In such case the next lower stratum if porous, as the Trenton, gas or oil may be reached.

8. In Ohio and Indiana the Trenton is usually overlaid by the Utica shale, at its highest levels not less than 100 feet below the sea level.

9. Here the Trenton is a dolomite if containing gas, oil or salt water.

10. In California, petroleum occurs in the lower rocks of the Cenezoic Age, Tertiary System, the Eocene beds. In Pennsylvania petroleum occurs in black or dark brown porous sandstones, of which there are from one to five several beds in different localities. The third bed of this kind of rock has

usually been found to yield petroleum in most liberal supplies of either gas or oil, but the fourth and fifth beds have often been found to be more petroliferous than the third.

DEPTH OF PETROLEUM WELLS.

SECTION 5.—1. These gas and oil wells have been sunk from 200 to 2,000 feet deep.

2. Where the Niagara limestone beds are on the surface the Trenton was found to be a gas reservoir. But where the lower Helderberg beds were on the surface the Trenton was an oil reservoir.

DEAD LINE.

SECTION 6.—1. In Ohio it was found that 400 feet below the sea level was the "dead line" as to depth; and oil has not in a single instance been found below this line. But instead of oil, salt water may be found in the reservoir below the "dead line."

THICKNESS OF THE PETROLEUM RESERVOIR STRATUM.

SECTION 7.—1. The elevation of the roof above the bottom "dead line" of salt water, marks the thickness of the gas and oil bearing reservoir rocks. Within these upper and lower bounds, in the petroleum fields, the thickness here varies from 150 to 175 feet.

2. I have taken these facts largely from Mr. Horton's report to the United States government and he says "That shale is never a petroliferous rock." Reservoirs may occur at different elevations, and the dead line several hundred feet below tide water.

3. The Trenton limestones were formed during the lower middle Eozoic Age and Silurian period. The rocks of this period were laid down in the marine waters of the Aqueous Age.

4. During this age of the earth the earth's crust was thin, often fissuring and pouring the hotest lavas into the universal ocean, heating the waters, destroying the dawning life, and sedimentating fossil remains

while precipitating carbonates of lime and forming what is now known in this country as Trenton limestones; the petrolific rocks.

5. Hence it has been said "That the Trenton limestone is one of the firmest and most massive and widespread stratum in the foundations of the North American continent," and probably equally wide-spread in all other continents. And this stratum is one of, if not the most petrolific of all of the stratified rock. So indicating the most abundant and wide-spread reservoirs of petroleum, for the uses of civilized peoples.

6. And wherever this stratum by volcanic action has been thrown by underlying waves of the earth's hot and liquid molten matter and then cooled and left in wave-like anticlinals and synclinals that the explorator may look for gas, oil and for artesian waters.

CHAPTER XV.

HISTORY OF OIL WELLS.

SECTION 1.—1. Ever since Job found oil in "the rocks of the land of Uz," where "the rock poured out oil," about 1800 B. C., this land east of Judea where Job had his possessions, has been supposed to be the province of Cush in Assyria, north of the Persian Gulf.

THE ORIGIN OF PETROLEUM.

2. Prof. Newberry says "That petroleum occurs most abundantly in subcarboniferous rocks of the Appalachain Chain."

3. It has also been said "That petroleum emanates from the lower Silurian shale." "That the petroleum reservoir must be underlaid by bituminous rocks or bituminous shales." "That a petroleum reservoir may occur in the rocks of any geological age, where there is an impervious roof, to a porous containing bed or

layer, and the elementary atoms below have by distillation and natural chemical action been set free, and reunited to form petroleum."

4. The elements of petroleum are among the original elements of the earth. And as science teaches us, that there has never been a single atom of matter lost or extinguished, we must conclude; that, as from natural chemical action in distilling the carbonates of hydrogen, petroleum has been originally formed. Notwithstanding we may continue to burn natural gas, and rock or mineral oils, the supply can never be exhausted so long as their atoms are set free to reunite and again re-produce petroleum. If not in the earth, by some artificial means yet to be invented and applied by human genius.

ACCORDING TO PROF. EDWARD ORTAN.

SEC. 2.—1. Petroleum is derived from organic matter.

2. It is much more largely derived from vegetable than from animal substances.

3. The petroleum of the Pennsylvania type is derived from the organic matter of bituminous shale and is of vegetable origin.

4. Petroleum of the Canada and Lima types is derived from limestones and is of animal origin.

5. Petroleum has been produced at normal temperatures of rocks in the Ohio fields, and is not a production of destructive distillation of bituminous shale.

6. The stock of petroleum in the rocks is already practically complete.

7. While we recognize the great credit to which Prof. Ortan is entitled for his researches on the subject of petroleum, we must be permitted to refresh his memory as to certain well-known scientific facts and principles in natural science.

SEC. 3.—1. *All organic matter* has its origin in the usual chemical combinations of free atoms, resulting

from and in germination, conception, growth, life and maturity of plants and animals.

2. *Destructive distillation* of animal and other organic bodies may occur through their being digested, corroded, decayed, oxydized, burned, and thus separating the contained atoms of matter and setting them free to recombine chemically into petroleum or other fluid and solid bodies.

3. *The original growth* of all plants and animals was near the surface of the earth, in the waters, on the earth's surface and in the air.

4. *Subsidences* and the flow of waters from higher to lower levels, during such subsidences and during upheavals and the flows of volcanic lavas, have been the chief causes of the burial and reupheavals of organic matters from which petroleum has heretofore been, and hereafter will continue to be distilled in the earth. Such distillation has probably taken place in a temperature of the buried organic material of about 400° F., as this temperature is required in the artificial manufacture of petroleum.

5. While the normal temperature of the earth within from 60 to 150 feet of the surface does not exceed from 55° to 70° F. And from 55 feet deep downward the heat increases at the rate of one degree for each succeeding 60 feet in depth.

6. Hence 15,000 feet or less below the earth's surface there must be about 400° F., or heat sufficient to distill petroleum from bituminous materials. And with a higher connected reservoir of a porous stratum in which the products of distillation may be confined, natural gas and mineral oils may hopefully be prospected for with the diamond drill.

7. We include in the term petroleum both natural gas, mineral oils and several other bituminous products. Either of these products may be discovered in the rocks above those of the Eozoic aged beds.

8. While making deep drillings or wells, artesian, mineral and salt waters may be found of great value. Artesian water is most likely to occur in a synclinal—petroleum on an anticlinal.

9. "That gas may be found, but not generally alone, where the trend of the arched stratum having an impervious roof occuring in coarse and porous sandstone of considerable thickness, or in fissures and fractures of closer grained rock beds which serve as a reservoir for gas and must underlie great depths of 500 to 25,000 feet of uncarboniferous (or a bed of impervious rocks.)"

10. "In Pennsylvania the oil strata are reached from the top of the ground by drilling through the following strata in the order to be named.

First, Several hundred feet of soft, fine grained shale.

Second, Sandstones bedded in shale.

This order occurs from three to five times as found at different localities, the paying oil flow being found in one or more of the sandstone reservoirs from the third to the fifth."

11. "In Ohio, the petroleum oil fields are drift covered plains. Their fertility of soil is only exceeded by those of the Russian oil fields," or the drift covered plains of Nebraska and states of the great plains east of the Rocky Mountains, yet to be developed as petroleum fields.

12. These plains rising from near the Mississippi and Missouri rivers, to the foot of the Rocky mountains from 800 feet to 1,500 feet, and upwards, above sea level.

13. "The wells of greatest productiveness in the oil fields of Lima, Ohio, are limited to depths of from 370 to 390 feet below the level of tide water."

14. "The oil and salt water bearing rock is a dolomite and Magnesian limestone. This stratum is found

to be at first a hard cap, of from 3 to 7 feet thick through which the drill is driven, then reaching a porous dolomite of from 7 to 15 feet thick, and below in this same dolomite stratum the salt water rock, a hard and fine grained rock is pierced, making altogether a depth of 30 feet.

15. Below this the experienced driller seldom drives his drill, as this has been proved to be the "dead line" for petroleum in these fields.

16. In the Indiana gas fields it is said "that the 'Guelph,' Metamorphosed, or Niagara and limestone, changed to a true dolmite at the surface of the ground, is a good limestone to burn, but a poor building rock. Next below the Niagara shales appear; below these comes

THE CLINTON LIMESTONES.

17. These occur with small outcroppings, in Southern Indiana; below these were found

18. The Cincinnati group of shale, that is, the Hudson River shale; passing below this the drill pierces a dark blue shale, black shale, an upper fossiliferous limestone of 15 to 30 feet thick, included in this group of 250 to 300 feet thick.

19. The drill then reaching the Utica shale, a stratum of black shale with its characteristic fauna, including Leptobolus insignus (Hall) Triarthus (Becki) then reaching

20. The Trenton limestone, there occurring as a dolomite and yielding oil, from under the table lands.

CHAPTER XVI.

OIL WELL INDUSTRIES.

Section 1.—1. In modern times oil well drillings have become one of the greatest industries in the United States, and with scientific and practical loca-

tions for such wells the chances are more than two to one that the drilling will pay a large dividend.

2. One of the first oil wells drilled in the United States was in 1854, at Petrolia, on Oil Creek, near Lake Erie, and the next was drilled in 1858, at Titusville, Pennsylvania.

3. But in 1860, the Pennsylvania oil fields were known to cover over 100 square miles.

4. From 1860 until 1871 there had been so many successful drillings made for oil in Pennsylvania and West Virginia, and Ohio, that it was then thought that the yield of petroleum from them would supply the world.

5. But no such conclusion would have been reached had the oil producers of that time have known the extent of the various useful purposes to which petroleum products were destined to be applied.

THE OHIO PETROLEUM FIELDS.

SEC. 2.—1. In 1884, a drilling, as an experiment, was made at Findlay, Ohio, 1100 feet deep, when the drill set loose a gas jet with great force. Here the drill passed a hard and impervious roof in the Trenton limestone, to a dolomitic reservoir in the same formation.

2. At North Baltimore, in the Findlay, Ohio, field an oil well was found which yielded in each 24 hours 5,000 barrels of oil. This was then thought to be the largest yield per day of any well tapping Trenton limestone, and the middle Silurian system of rocks, while the first flowing well struck in 1861, yielded only 1,000 barrels per day.

3. A well drilled at Sherman, Ohio, yielded oil at the aggregate of 225,000 barrels per year. A well at Noble yielded 500,000 barrels in the first year after it was drilled.

4. The Lima oil fields in Ohio from the time the first well was drilled on the farm owned by J. W.

Ridenorer put into tanks 2,760 barrels the first twenty-four hours a dark colored oil.

5. Several oil wells were drilled at Adams, Ohio. Here the drillings were driven 100 feet deeper than the Findlay wells, and to levels below tide water 2,000 feet from each other, and 400 feet below tide water proved to be here the "dead line," below which oil was not in a single instance found.

6. The many other and more recent discoveries of petroleum included with all others in Ohio, Pennsylvania and Indiana pointed the oil explorator to the Mercer fields in 1886 when oil was there discovered.

EXPORTING PETROLEUM.

Sec. 3.—1. In 1870 and before that time the total exports of mineral oil had reached the value of about \$19,304,224, and the total value of petroleum products reached in value \$46,574,970.

2. And in 1876 the value of petroleum products delivered at the sea board equalled in value \$300,000,000. The total products at the wells were estimated at a value of \$400,000,000.

3. The price of refined petroleum oil in London from America was 6¼ cents per gallon in 1879.

4. In 1880 the commercial oil industries had become so great that pipe lines began to be laid to convey the products of crude oil from the wells to refineries near the sea. The products for 1880 are said to have been (perhaps increased) 15,765,800 barrels, and the exports 420,000,000 gallons.

CHAPTER XVII.

THE INDIANA GAS WELLS.

Section 1.—1. It has been noticed that the productiveness of the several petroleum bearing forma-

tions increases as these and the reservoirs are found to be buried deeper in the earth.

2. The Indiana gas wells have been drilled about 875 to 975 feet deep.

3. The products of the yield of gas from any given well during twenty-four hours is usually stated as a given number of cubic feet per day.

4. In June, 1887, a well drilled at Fairmount, Grant county, Indiana, yielded 11,500,000 cubic feet per day.

5. A gas well at Van Buren, Ohio, yielded 15,-000,000 cubic feet per day.

6. Many other wells in Indiana and in Ohio, severally yielded from 1,000,000 variously up to 4,-000,000 cubic feet per day, and others still more, from 5,000,000 up to 11,000,000 cubic feet per day.

7. A gas well in either Ohio or Indiana would be considered of little or no value if its yield did not exceed 500,000 cubic feet per day, if the well be cased by a 4½ inch piping.

8. The main gas field in Indiana is within the counties of Deleware, Blackford, Madison, Grant, Hamilton and Howard, all in a fine agricultural region.

GAS BOOMING TOWNS.

SECTION 2.—1. The records of gas well drillings show that in 1887 a well drilled to the depth of 875 feet at the town of Muncie, reaching seventy feet below tide water, yielding a large supply of gas caused many factories to be located at this town.

2. In the same year a little north of Muncie at Hartford City, gas was found by drilling to the depth of 963 feet, reaching eighty feet below tide water. In sinking this well the drill first passed through 126 feet of drift. 2nd, 149 feet of limestone. 3d, 688 feet of shale. 4th, Then reaching in the Trenton limestone the gas reservoir, which yielded from 875,000 to 1,000,000 cubic feet of gas per day,

gushing up with a force of 350 pounds pressure to the square inch.

A second well drilled at Hartford yielded 10,000,000 cubic feet per day.

3. A well at Anderson yielded 13,500,000 cubic feet per day.

A well at Marion yielded 11,500,000 feet per day.

4. A successful well drilling at Nobleville through sixty feet of drift, 400 feet of limestone, 392 feet of shale, and to the depths of seven feet into a dolomite Trenton limestone, reached gas eighty-seven feet below tide water, on the Wainright farm. It yielded about 7,000,000 cubic feet of gas per day.

5. A well at Kokomo which was drilled through sixty feet of drift, 360 feet of Niagara water limestone, 280 feet of blue shale, 236 feet of dark and brown shale, and eight feet into the Trenton limestone, where the drilling tapped the gas reservoir at a depth of 944 feet. But the drillers in hope of a greater flow drove the drill twenty-two feet deeper, when the gas was cut off by a flow of salt water. The greatest flow of gas was just before the salt water was reached.

6. This experiment proved the fact that gas could be had at Kokomo. And two other wells were at once driven here, one yielding 820,000 and the other 1,123,200 cubic feet of gas per day.

7. A fifth well drilled 912 feet deep at Kokomo; the lowest fourteen feet in the Trenton rocks, yielded 7,500,000 cubic feet cf gas per day.

8. In one instance a well drilled only 525 feet deep found a reservoir of gas in the shale.

9. Aside from the "dead line" as a caution to drillers for petroleum, if on reaching the Trenton rock, it should not be capped with a hard and impervious roof, or if under the roof the Trenton limestone be not dolomitized and porous, there will be but faint hopes for petroleum in that stratum.

10. The gas found in the petroleum fields of Ohio and Indiana is of about the same as to its purity.

CHAPTER XVIII.

THE IMPORTANCE OF DEEP WELL DRILLINGS.

SECTION 1.—1 The importance of deep well drilling for experimental purposes can be scarcely overestimated. And this is especially true within the Great Plains and semi-arid regions.

2. In making drillings in these regions the driller will usually find at the surface the same aged drift east of the Rocky Mountains, as we have shown, has been found west of the Appalachian Chain, within Ohio and Indiana, and all within the basin of the Mississippi and Missouri rivers.

3. In the west the question of irrigation of the arid regions, for the purpose of finding homes for the homeless and the increasing multitudes of such as our children and grand children increase in numbers makes the question of providing such homes of the greatest national importance to our future civilization. Shall we as a people degenerate into nomads for the want of homes? Homes must be provided! or those unprovided for must nomadize! The home is the inducement to good citizenship. What interest can one have in any community, any country in which he cannot obtain and retain a home?

4. To utilize the Great Plains by irrigatian and and otherwise for homes should be the highest ambition, as it would be the greatest patriotism of the statesmen.

5. In boring deep wells for artesian water, gas, oil, salt water, coal and for the discovery of building rock and experimental purposes the diamond drill should

always be used, the core carefully withdrawn, measured, and a correct record made of all beds of earth, rocks and strata passed by the drillings, and the well safely cased with iron pipings.

6. The internal pressure of closed pipes of gas has been found in some instances to equal 950 pounds to the square inch. In other cases more or less. Some 500 pounds and so on down to a merely sensible pressure.

7. "The force of the pressure of gas and of oil are said to equal that of salt water behind the petroleum" in regions where the three occur.

8. The value of natural gas discoveries is almost invaluable because there are so many purposes to which it may be applied.

9. The value of gas for heating as compared with the best Pennsylvania coal is said "to be as one ton of coal to 31,000 cubic feet of natural gas.

10. But counting the weight, waste and expense of handling of coal, it will make the relative value for heating equal one ton of coal to but 15,000 cubic feet of natural gas in the immediate vicinity of the Indiana gas fields."

11. If we take into our calculation, regions of great distances from the coal fields and can there, as upon the great arid plains, discover natural gas, the importance of such discovery will make in favor of gas a vastly greater difference in its value.

12. And when we consider the cost of transportation as between petroleum and coal here again everything is in favor of gas, and oil which may be piped, while coal must be carried by hand, horse and steam power over land and water.

13. The reader may make his own estimate, having sufficient facts and data before him.

In Findlay, Ohio, the city is piped for the use of gas from the gas wells, and there the charge for

natural gas for each cooking stove per month is 15 cents.

14. Natural gas at Findlay is in general use for generating steam power, wherever needed for manufacturing purposes. And jets of burning gas are used for welding iron, melting and making glass, and taking the place of coal for fuel at less than two-thirds its cost.

15. At Lima, Ohio, the rolling mills and nail mills are run, and bricks burnt by heat from burning natural gas.

Where these developments are practical and known to the people they show their appreciation.

16. In the petroleum field of Canada, Pennsylvania, West Virginia, Western Ohio and Northern Indiana the discoveries of mineral oil and natural gas have had the effect of inducing the people in nearly every county seat to drill for petroleum, and to have been so generally successful, that there, where before these drillings there were but a few people in small towns; within the past ten years these towns have been built up into large manufacturing cities, now containing many thousands of people. Real estate has rapidly advanced in value, and many of the residents within this period have become rich.

THE FARMER SHOULD BE ACTUAL LAND OWNER.

SEC. 2.—1. Title to irrigated lands should include the title to the water necessary to irrigate the land. The general government should stop the sale of large bodies of desert lands, to capitalists who may irrigate these lands then sell at greatly advanced prices, and rent the water so as to absorb the value of the productions of the actual farmer.

2. The government by the necessary congressional legislation should develop and apply the neccessary water supply to irrigate the arid lands, then give or sell them to actual homesteaders in farms not exceed

ing twenty acres to each head of a family. This may be done so as to provide a revenue sufficient to keep advancing these irrigation improvements.

WILL IRRIGATION PAY?

SEC. 3.—1. It will be further seen by the following table, how well irrigation has been made to pay, as "compiled from census and California State Horticultural reports by Palmer & Chapin, in their district of the Tierra Bonita Colonies, in Los Angeles County, California.

IRRIGATION VERSUS NON-IRRIGATION.

Population of Los Angeles County, 1870, 15,309; 1890, 101,454. Increase over 660 per cent.

IRRIGATION AS A POPULATION MAGNET.

Covering a period of twenty years—1870 to 1890.

Population of 7 irrigated Counties { 1870—40,849.. / 1890—250,283.
Increase 510 per cent.

Population of 7 Non-Irrigated Counties { 1870—41,131.. / 1890—67,778.. Increase 64 per cent.

WEALTH of Los Angeles County, 1870, $6,918,074; 1890, $67,121,610. Increase over 955 per cent.

IRRIGATION AS A WEALTH PRODUCER.

Wealth in 7 Irrigated Counties { 1870—$22,513,820.. / 1890—$207,216,567.
Increase 820 per cent.

Wealth in 7 Non-Irrigated Counties { 1870—$12,550,341.. / 1890—$45,039,322.. Increase 258 per cent.

With 20 per cent of the total population of the State, Southern California secured 50 per cent of the total increase in population, 1870-1890.

These results have by irrigation been secured on lands before arid and desert.

2. The prospecting of such lands with deep drilling where surface water is not available, as we have shown, will in many cases lead to the discovery of artesian

water, petroleum in many forms, such as gas, rock oil, asphaltum, napthaline, or some one of the many other valuable minerals, which go to make up a rich and prosperous people. The wealth so produced should by law be secured to the operative and actual producers, so as to sustain these in the highest state of civilization.

WHAT SHALL THE IRRIGATOR RAISE?

SEC. 4.—1. The comparative value of wheat with other common concentrated foods fed dairy cattle, can be noted in the following table, which shows the number of pounds of each part digestible in 100 pounds:

	Protein Lbs.	Carbo-hydrates Lbs.	Fat Lbs.	Nutritive ratio.
Wheat	9.3	55.8	1.8	1: 6.4
Corn	7.1	62.7	4.2	1:10.1
Oats...................	8.3	44.7	4.1	1: 5.9
Wheat Bran	12.6	44.1	2.9	1: 4.0

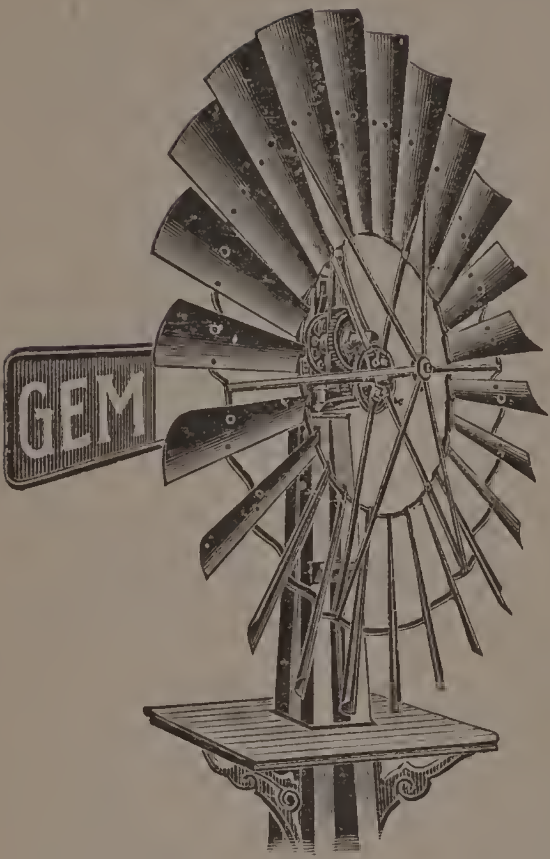
According to this table, wheat has more digestible protein than corn or oats, but less than wheat bran. It certainly has a feeding value of high class, and feeders are beginning to realize that this is the case.

2. It is estimated that the average profit per acre to the potato growers in the Greely country, Colorado, is about $67.50

3. In 1893 the average yield of fruits per acre in the state of Colorado, as shown by the fruit growers association of that state were as follows: Strawberries, $350, blackberries, $600; raspberries, $400; currants, $500.

4. A Colorado gardner from three acres of land along the Platte river, sold this year $1500 worth of pickled onions.

IRRIGATION.



WITH BABBIT
OR
GRAPHITE BEARINGS.

The 10 foot Gem with 10 inch stroke, and the 12 foot Gem with 12 inch stroke, are best adapted to Irrigating Pumps.

FOR WELLS FROM 15 TO 25 FEET DEEP.

5 in. Gause Pump, 10 ft. Gem or 10 ft. Halladay Mill
6 " " " 12 ft. Gem or 13 ft. Halladay.
8 " " " 12 ft. Gem or 14 ft. Halladay.

In some cases it may be necessary to use the mill on the medium length stroke, but they will in most cases work nicely on the long stroke.

FOR LIFTING WATER FROM 25 TO 40 FEET.

4 inch Gause Pump, 8 foot Gem or 10 foot Halladay.
5 " " " 10 " " " 12 " "
6 " " " 12 " " " 14 " "
8 " " " 16 " Halladay or 16 foot U. S.

The Gem in all cases herein to be Triple Motion, Long Stroke.

The 12 foot Gem or 14 foot U. S. or Halladay, will operate the 4 or 5 inch pumps in wells from 40 to 75 feet deep.

These combinations are adapted to either open or drive wells.

IRA C. HUBBEL.

We have here taken the liberty of giving nearly in full a paper by Mr. Hubbel as printed by the Irrigation Farmer. It being too scientific to leave out.

IRRIGATION MACHINERY.

During the Inter-state Irrigation Convention held in Omaha, March 1, 1894, the following interesting paper on the subject of irrigation machinery was read by Ira C. Hubbel, of Kansas City, Mo.:

"MR. PRESIDENT AND GENTLEMEN: It is germain to this subject to here say that every one owes it to himself and to his neighbor to irrigate every foot of ground possible, for as additional acres are watered year after year, the rainfall will be increased.

"Now for the modes of handling water.

"In that we are all perhaps more accustomed to windmills employed in pumping water than other appliances, suppose we see what can be done with this means for raising water. Windmills have a rated horse power capacity and this power is predicated upon a wind of twenty miles per hour, and which is termed a strong wind. A better average wind for our purpose, and one considered more conservative, is of fifteen miles per hour. In this connection it would be well to remember that the power of a windmill of any diameter increases or decreases as the square of the velocity of the wind in miles per hour, and that, therefore, a mill of 3-horse power capacity in a 15-mile wind will have but $1\frac{1}{3}$ horse power in a 10-mile wind.

"It should also be remembered that a mill of any diameter will handle a greater or less quantity of water as the total vertical height of the discharge in feet is decreased or increased—for instance, a mill that raise 100 gallons per minute 100 feet vertically will elevate

200 gallons per minute 50 feet vertically, for 100 gallons multiplied by 100 feet and by 8⅓ pounds (the weight of one gallon of water) and by one minute of time equal .83333 foot pounds, and 200 multiplied by 50 multiplied by 8⅓ multiplied by one equal .83333 foot pounds. Here is a most excellent place to say that the habit of resolving work to be done to foot pounds is good practice, and it will restrain some of us from chasing perpetual motion. Remember above all things that one pound of any substance (no matter what) raised one foot vertically in one minute of time, or the equivalent, requires a mechanical force of one foot pound plus the friction that is due to the means employed, and you may as well try to lift yourself into heaven by your boot tops as to evade this principle.

"A cubic foot of water weighs approximately sixty two and one-half pounds and contains approximately seven and one-half gallons of eight and one-third pounds each. A mechanical horse power is .33000 foot pounds. It therefore requires .0002527 (millionths) horse power to raise one gallon of water one foot vertically in one minute. This is net work realized, and makes no allowance for friction at any point. Allowing for all friction about 34 per cent the constant becomes .00034 (one hundred thousandths.) Dividing one horse power by this latter constant we find that one horse power will raise 2,941.1765 gallons of water one foot, 1,470 two feet, or about 294 gallons ten feet, or 118 gallons twenty-five feet in one minute. Remember in checking these figures that these quantities are predicated upon an allowance of a little over 34 per cent for friction.

A PRACTICAL APPLICATION.

"Now for a practical application of the constant .00034. A farmer has a 10-foot windmill. His well is 30 feet deep, has plenty of water, and by raising the water on to a knoll 25 feet above the top of the well he

can construct a reservoir, say 150 feet long, 75 feet wide, and say four feet deep. How much water can he rely upon his mill furnishing? Basing the calculation upon the average wind of 15 miles per hour, the 10-foot mill will yield .56 horse power, which, divided by (30 plus 25 equals 55 times .00034) equals 29.9465 gallons per minute. Proof, 2941.1765 gallons one net horse power will raise one foot in one minute, multiplied by 56, divided by 55 equals 29.9465. Another proof, 29.9465 gallons multiplied by 83 pounds multiplied by 55 feet multiplied by 1 minute divided by .33000 equals 41592 net horse power to which add 34.64 per cent, which is the allowance for friction in the constant .00034, we have actual horse power .55999. It is therefore safe to rely upon 30 gallons per minute or 1,800 gallons per hour. The reservoir specified will hold about 340,000 gallons of water. It is conceded that a mill will work about one-third of the twenty-four hours, or eight hours, yielding a maximum quantity of 14,400 gallons per day, or filling the reservoir in about twenty-four days, or in the 180 days water is wanted, this 10-foot mill will yield about 2,-550,000 gallons, or sufficient water to take care of ten acres of ground. Whilst it is true that the force of the wind is as the square of its volocity, so is it true that the power of windmills is as the square of their diameter; therefore, a 12-foot wheel will do nearly 50 per cent more work than a 10-foot, and a 14-foot mill will do nearly 100 per cent more work than a 10-foot. Therefore, with an ample water supply the farmer in the case just cited would be amply justified in throwing away the 10-foot wheel and erecting a 14-foot mill.

"The windmill only has been spoken of so far. To elevate water by wind power requires some form of a pump head and cylinder operated by the mill. To facilitate selection of a cylinder for the work, as has been endeavored to help select a windmill for the duty, other constants are here given. Drawing from de-

ductions of Mr. B. A. McAllister in his paper of November 23, 1893, at Wichita, it is determined that an acre of land will need during the season 32,670 cubic feet, or 245,900 gallons of water, or an average of 1,366 gallons per day (season called 180 days); or ten acres require 13,660 gallons per day. Wind power for the day, eight hours, or 1,706¼ gallons per hour, or about 28½ gallons per minute.

"If you will square the diameter in inches of the water piston or plunger in a cylinder or pump and multiply that result by the constant .00034 and by the length of the stroke in inches, and by the number of strokes the piston or plunger makes per minute, you have the actual capacity of the cylinder in gallons per minute. There is, however, a loss here, as more or less water leaks past the piston or plunger, so that in reality we only realize about 80 per cent efficiency; therefore, our constant should be for actual results .00272 (one hundred thousandths.) The capacity of a cylinder 6-inch diameter, 8-inch stroke, 40 strokes per minute, determined by long process, is: Area of 6-inch piston equals 6 multiplied by 6 multiplied by .7854 equals 28.2744 multiplied by 8 inches multiplied by 40 divided by 231 equals 39,168 gallons theoretical capacity multiplied by 80 per cent equals 31.3344 gallons actual. Determined by the constant, 6 multiplied by 6 multiplied by 8 multiplied by 40 multiplied by .00272 equals 31,344 gallons. In the problem just stated we want 28½ gallons per minute for our 10-acre tract of land. Assuming that the mill employed will make an average of 40 revolutions per minute, and the length of the stroke to be 8 inches; the square root of 28.5 divided by (.00272 multiplied by 40 multiplied by 8) equals 5.72, or say a cylinder 6 inches in diameter.

"From the preceding the size of the mill or cylinder for any location may be determined and the farmer purchase an article he knows will do his work. To demonstrate the author's faith in the figures herein

given, he begs to say that if the farmers will supply the water he will furnish the address of reputable dealers who will furnish windmills and pumps guaranteeing the results given.

ANOTHER SYSTEM EXPLAINED.

"We pass now to another mode of handling water.

"In many places there are running streams, but the expense of a ditch with all implied, is a prohibitory tariff so far as the individual farmer is concerned. How is he going to get some of that water on to his higher ground? In such instances hydraulic rams will be found especially adapted. In general terms, you can safely rely upon the ram raising and discharging one-seventh of the water passing to an elevation five times the fall. For example, suppose location lies where a fall of ten feet can be had by constructing a short ditch or inexpensive dam and that a constant supply of 350 gallons of water per minute can be relied upon; then the ram will deliver into a reservoir fifty feet above the ram fifty gallons of water per minute or 3,000 gallons per hour, or 72,000 per day, for a ram, like Pinkerton, never sleeps! A ram of this capacity would not cost to exceed $250.

"In using rams the ram should be about 50 feet from the supply and the water should be led to the ram through a pipe of ample diameter and as nearly straight as possible, and the discharge pipe should be full size for quantity of water to be handled and as straight as conditions will permit. The quantity of water discharged by the ram will decrease as the vertical height of the discharge increases over five times the height of the fall. Here no other formulæ can be given. Each location must be treated independently.

"In similiar locations and with artificial lakes or reservoirs made by damming draws, pulsometers, ejectors, jet pumps, centrifugal pumps, rotary pumps and steam pumps are also applicable.

"Treating them in the order named, pulsometers, ejectors and jet pumps. These three means are classified under one head, in that to a great extent they trot in the same class. With each must be employed a steam boiler to supply the necessary power for operating, and your speaker considers this impractical in the average instance, and where the conditions justify using a boiler, then unquestionably the means to be employed are found in duplex pumping engines, and of which something will be said later. In any place where pulsometers, ejectors or jet pumps would be considered, your speaker earnestly recommends the use of a centrifugal pump driven by a gasoline engine, in that the combination requires a minimum of attention; provided the purchaser does unduly scrimp his appropriation for the plant.

"A 4-inch centrifugal pump with a gasoline engine of 2½ net horse power will raise 9,000 gallons of water per hour twenty-five feet vertically, and it can be operated twenty-four hours per day, or less as desired, and at nominal expense, as will be subsequently shown. In purchasing a combination of this class get the best that is offered, and have both the engine and the pump supplied with liberal oil cups for all bearings, so that after starting the combination can be left to itself two to four hours as occasion may demand. Topographical conditions favorable, many a farmer can irrigate a large portion of a quarter section with the combination of which we have just spoken.

PUMPED BY AN ENGINE.

"Referring again to Mr. McAllister's deductions: An acre requires during the season 245,900 gallons of water. Running our gasoline engine eight hours per day (same as a windmill) we get 72,000 gallons of water per day, or 12,960,000 for the season, or sufficient for 52 acres. If the pumping plant is run 10 hours per day, the result is increased in the same pro-

portion, and 65 acres are covered. Such a combination will cost less than $650 delivered at a very remote point and including the services of a competent engineer to thoroughly instruct in the use of the apparatus. The estimate of cost is upon an exceedingly liberal basis for freight, etc. To this cost must be added such piping, etc., as necessary, and a wildly liberal allowance for this would be $150, or a total of $800, to make sure a crop year in and year out on a minimum of 50 acres of ground. Will it pay? The cost of the pumping plant is $16 per acre. Statistics show that the grain per bushel on irrigated land is far in excess of the yield on land not regularly watered. One instance reported shows a gain of about 400 per cent. Suppose we get 16 bushels of wheat without irrigation and 24 with, gain eight bushels per acre at 40 cents per bushel, yields $3.20 net gain per acre per year, or one-fifth the cost of our plant. Twenty per cent on an investment is good returns. In reality it is often the difference between a full crop and no crop on the 52 acres.

"Centrifugal pumps can be used advantageously only on moderate heights; for greater heights power or rotary pumps may be employed. The cost of these pumps is somewhat in excess of the ones just mentioned. A power pump of same capacity as the centrifugal pump mentioned for the duty specified would increase the cost by about $200, and if same quantity of water was to be raised to a height of 50 feet it would require an engine of twice the net horse power of the one specified, because of the additional elevation, and which would add to our cost further about $250, or making a new total of $1,250 to put water up 50 feet vertically for 50 acres of ground, or $25 per acre. In California parties have expended as much as $200 per acre for the water right alone.

"To operate a $2\frac{1}{2}$-horse power gasoline engine ten hours per day will cost less than $40 per month, figur-

ing the cost of gasoline at 20 cents a gallon, against an average price of 10 cents; allowing one gallon of lubricating oil at 25 cents per gallon per day, and for sundry odds and ends 95 cents per day. The actual cost would probably be nearer $20 than $40, but we do not want to mislead any one. For capacities of this class of pumps reference must be had to the catalogues of the several makers.

"Taking up the question of steam pumps this paper is ended.

"In situations where large acreage is to be covered, thereby demanding large volumes of water, the service will be best performed by compound duplex pumping engines especially designed to meet the requirements of the particular location. To, however, start thought an instance is here cited where the speaker was called upon for specifications for a pumping plant having a capacity 4,000,000 gallons per twenty-four hours, or about 2,778 gallons per minute, with a total vertical lift of 65 feet. For this plant it was recommended to use a complete duplicate plant—two compound duplex engines, two horizontal return tubular boilers set in battery with independent furnaces, a duplex boiler feeder with an aspirator for auxiliary feed, and the piping so arranged that either boiler could be used to drive either pumping engine, or both boilers to drive both, or in any way circumstances make advisable. Such a plant erected complete, ready for use anywhere within 400 miles of the Missouri river rating points, would cost approximately $6,000, or less, as freights, etc., were less. This exclusive of water pipes to carry water to distributing point, which of cast iron and for some 4,000 feet, as required at the point in question, would cost $8,000 according to location. Tiling can be safely used for the discharge pipe in a great many instances, and thereby the expense of distribution materially decreased. Such a plant will water about 3,000 acres of land.

COST OF OPERATION.

"The cost of operation of this plant will be about as follows per month, working full capacity:

Engineers, first and second, who will do the firing......	$ 175
Oils, waste, etc....	25
Coal, at $3 per ton, slack.	450
Incidental expenses..................................	150
Total per month.......................	$ 800
Or for six months....................................	$4,800

"Or a running expense of about $1.60 per acre for the season, independent of interest on first cost and depreciation of pumping plant, which at 8 per cent each would be $860, or 32 cents additional per acre, and to this add 8 per cent interest on cost of pipe line, and say 4 per cent on cost of pipe line or depreciation, making further charge of $960, or 32 cents per acre, or a total cost of $6,720, or $2.24 per acre.

"The plant just outlined will be erected by a gentleman in a neighboring state for a tract of land of much less acreage than the plant's actual capacity. His water snpply will be maintained by a dam constructed across a draw, whereby an ample supply of water is secured."

TO ACCOMPLISH BEST RESULTS

in Nebraska, Kansas, Oklahoma, or other states of similiar location, from 5 to 10 inches of water should be applied each season, varying according to the rain fall. In states further west perhaps more would be needed.

Windmills will furnish water profitably from wells as deep as 200 feet for irrigating all kinds of fruits and vegetables.

Apples, cherries, peaches, grapes, blackberries, raspberries, and other small fruits will produce abundantly and profitably in any of the western states, if well watered.

Windmill irrigation is no experiment, it has been tried thoroughly and never found wanting.

The wind blows at a pumping velocity on an average of 10 hours per day for the entire year.

FACTS WORTH REMEMBERING.

27,154 gallons of water will cover one acre one inch in depth.

A reservoir containing one acre of ground filled with water four feet in depth contains 1,303,392 gallons, which is sufficient to cover 48 acres one inch in depth.

A miners inch of water is equal to 9 gallons per minute.

A cubic foot of water contains 7.48 gallons and weighs $62\frac{1}{2}$ pounds.

One gallon of water contains 231 cubic inches and weighs $8\frac{1}{3}$ pounds.

Doubling the diameter of the cylinder increases its capacity four times.

Square the diameter of the cylinder, multiply by length of stroke in inches, then multiply by .0034 and you have the capacity per stroke in gallons.

LIST PRICES—GAUSE PUMPS.

Fig 1. For Drive Wells.

4 inch bore, 5 feet long, for 4—1½ in. suction pipes............. $27.00
5 " " 5 " " " 4—2 " " " 34.00
6 " " 5 " " " 4—2 " " " 44.00
8 " " 6 " " " 6—2 " " " 70.00

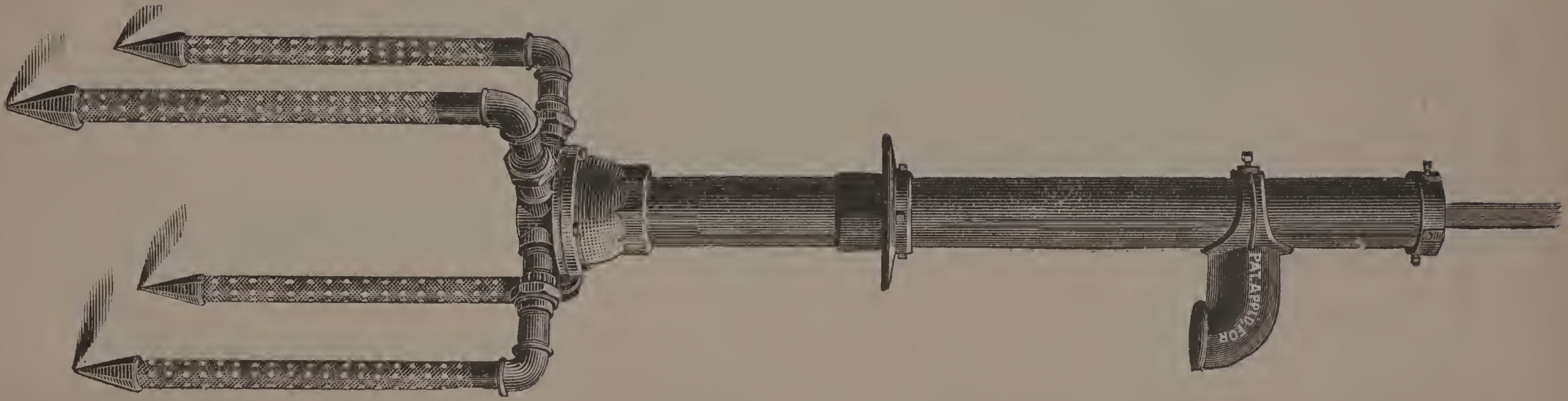
Fig. 2. For Open Wells.

4 inch bore, 5 feet long, for 3 inch suction pipe................ $23.00
5 " " 5 " " " 4 " " " 30.00
6 " " 5 " " " 5 " " " 39.00
8 " " 6 " " " 6 " " " 63.00

CAPACITY OF GAUSE PUMP.

The Gause Pump is fitted with a brass lined cylinder.

4 inch Gause Pump on 12 inch stroke, 2,000 to 2,500 gallons per hour.
5 " " " " 12 " " 2,500 " 3,000 " " "
6 " " " " 12 " " 3,500 " 4,000 " " "
8 " " " " 12 " " 5,500 " 6,000 " " "



STANDARD WROUGHT IRON PIPE.

Revised and Adopted April 13, 1893.

BUTT-WELDED.

Nominal Size Inside Diameter INCHES	Price per foot Black	Price per foot Galvanized	Nominal Weight per foot. POUNDS
¾	$ .07½	$ .10	1.12
1	.11	.14	1.67
1¼	.14½	.19	2.24

LAP-WELDED.

Nominal Size Inside Diameter INCHES	Price per foot Black	Price per foot Galvanized	Nominal Weight per foot POUNDS
1½	$ .24	$ .28	2.68
2	.33	.38	3.61
2½	.50	.57	5.74
3	.64	.70	7.54
4	.90	1.05	10.66
5	1.28	1.60	14.50
6	1.65	2.00	18.76
7	2.10		23.27
8	2.75		28.18

PRICE LIST BRASS JACKET POINTS.

MADE OF GALVANIZED WROUGHT IRON PIPE.

Trade Number	Size in Diameter	Length of Point	Length of Jacket	No. of Holes	Number of Gauze, 60, Price per Dozen
136	1½ in.	24 in.	18 in.	120	$ 48.00
140	1½ "	30 "	24 "	162	60.00
144	1½ "	36 "	30 "	198	72.00
146	1½ "	42 "	36 "	240	84.00
148	1½ "	48 "	42 "	276	96.00
150	1½ "	54 "	48 "	312	108.00
152	1½ "	60 "	54 "	348	120.00
154	1½ "	66 "	60 "	384	132.00
156	1½ "	72 "	66 "	420	144.00
160	2 "	24 "	18 "	144	75.00
164	2 "	30 "	24 "	208	90.00
168	2 "	36 "	30 "	264	105.00
170	2 "	42 "	36 "	288	120.00
172	2 "	48 "	42 "	336	135.00

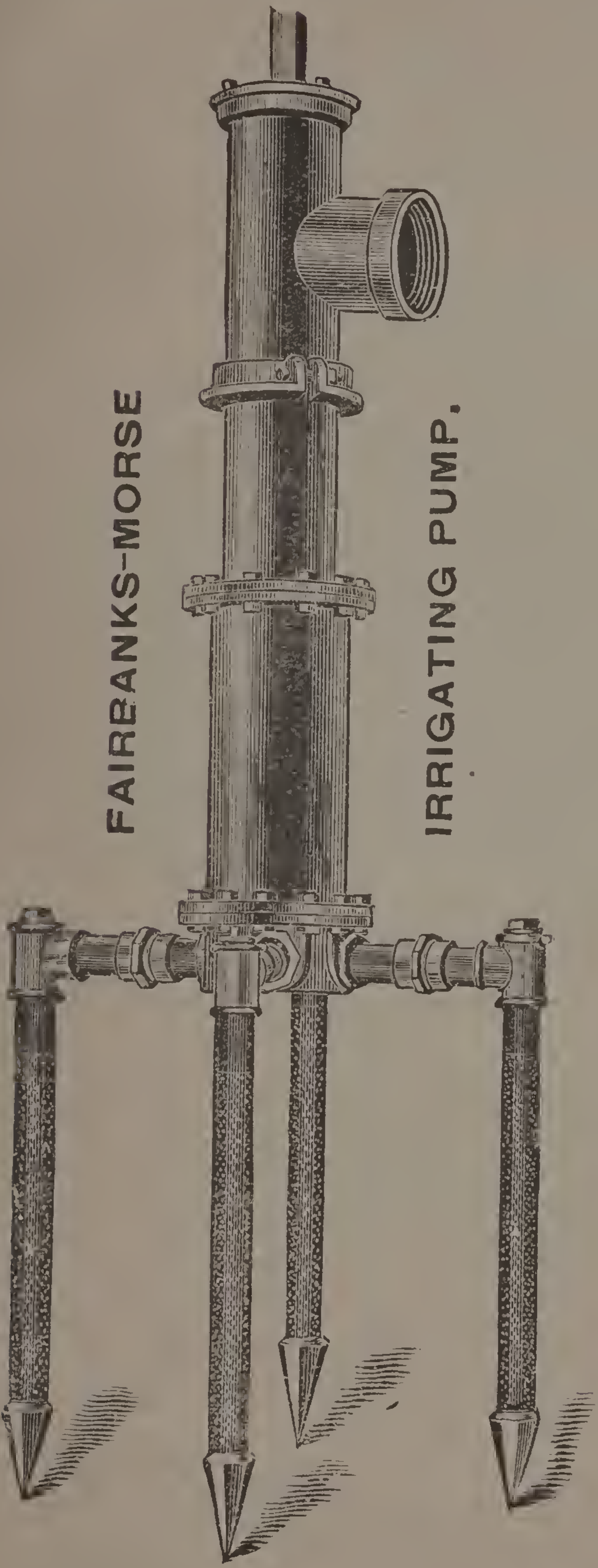
PRICE LIST OF FITTINGS FOR GAUSE PUMPS.

	1½ in.	2 in.
Elbows	$ .35	$ .50
Nipples	.38	.49
Unions	.60	.80

In fitting pumps for open wells, the cylinder can be placed from 10 to 15 feet above water and use smaller size pipe for suction.

UNITED STATES SUPPLY CO.,
Omaha, Nebraska.

FAIRBANKS, MORSE & CO.



PRICE LIST NEBRASKA PUMPS.

Size No.	Cylinder			Capacity in gallons per inch of stroke	Diameter Suction Flange	Weight, pounds, including 10 ft. Discharge pipe, no suction pipe nor point	Price complete as per cut, with 10 ft. Spiral Galvanized Pipe, but no suction pipe or point included	Add for each additional foot of discharge pipe ordered	Drive Pt.	
	Diameter	Length	Maximum Stroke						Diameter in inches	Price per foot No. 60 gauge
4	6	18	15	.1224	4	175	$ 30.00	$0.80	4½	$4.65
5	8	18	15	.2176	6	250	45.00	1.00	5	4.65
									6	5.40
6	10	18	15	.34	6	360	60.00	1.25	8	7.65
7	12	20	16	.4896	8	560	85.00	1 60	10	12.65

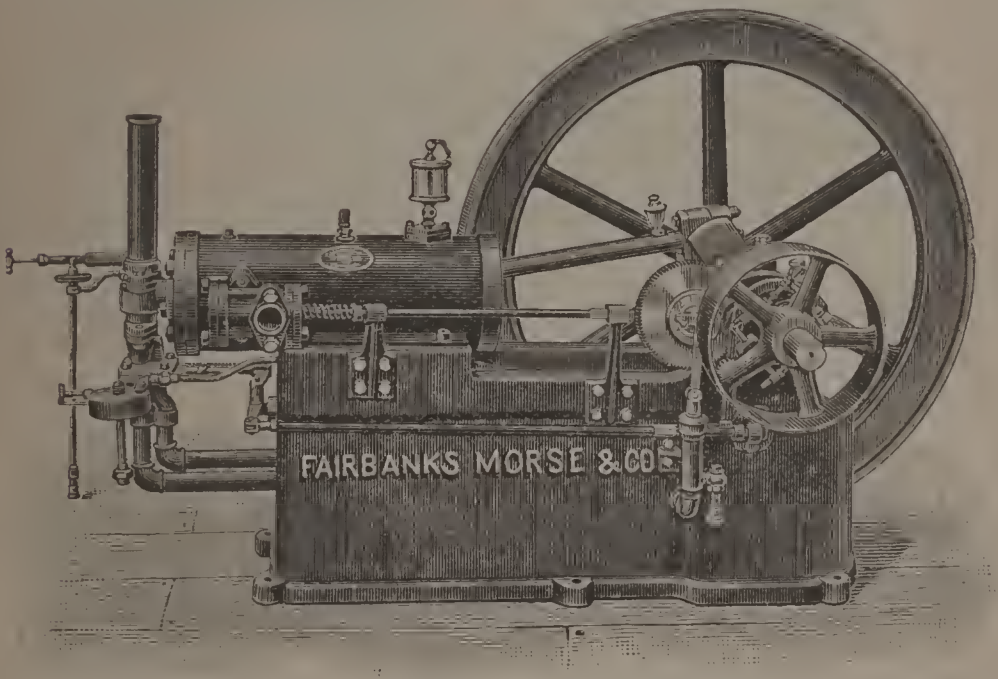
We give capacities of these pumps "per inch of stroke" to help you get capacity quickly for any desired length of stroke. For instance: 6 inch cylinder, 8 inch stroke, yields .1224x8 or .9792 gallons or nearly 1 gallon per stroke, or on 10 inch stroke this cylinder will discharge .1224x10 or 1.224 gallons per stroke.

For price on iron pipe for suction pipe, see any standard list, and for smaller sizes of drive points, see standard lists.

THE FAIRBANKS-CHARTER GASOLINE ENGINE.

We claim that "The Fairbanks-Charter Gas Engine" is without exception the best engine of the kind.

It is exceedingly simple in construction, easy in operation; combines a less number of parts than any other make of engine, and daily demonstrates its superiority over others.

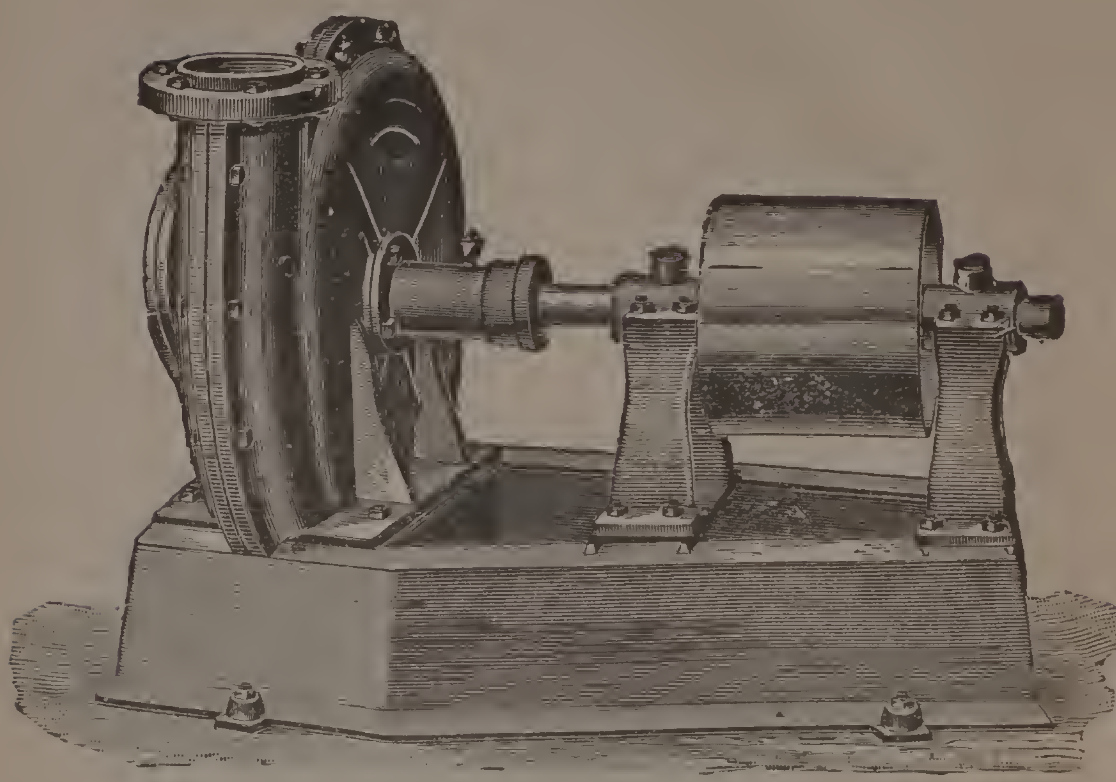


No.	Actual Horse Power	Indicated Horse Power	Pulley on Engine Shaft	Speed of Engine	Shipping Weight complete	Price Complete without Water Tank
0	2½	3	12x 4	300	1,700	$........
1	3½	4½	16x 6	250	2,150	....
2	5¼	7	18x 8	225	3,200	....
3	7¼	10	24x10	200	4,100	....
4	10½	14	28x12	180	5,800	....
5	15	20	32x14	175	7,500	....
6	27	36	40x18	160	13,000	....
7	38	50	44x20	160	16,000	....
8	75	95	48x24	150	24,000	....

Pulleys are made with straight faces for shifting belts.

We furnish instructions for setting up and operating "The Fairbanks-Charter Engines," together with foundation plans and dimension sheets.

FAIRBANKS-MORSE CENTRIFUGAL PUMPS.



Simplest, most durable and of highest efficiency of any pumps made within their range of duty.

No valves, no piston, no "nothing," just pump.

Our pumps will handle any kind of water, and without injury to the pump, whether the water is "loaded with sand, gravel or buck-shot."

Our patterns are new and cover all late improvements: pumps are heavy and substantial, and as the only parts to wear are the bearings for the shaft, the wear is practically nothing if oil is properly used. We are prepared to furnish right or left hand pumps. The cut shows a right hand pump.

LIST OF CAPACITIES AND PRICES.

Size discharge opening in inches	Economical capacity in gallons per minute	Actual capacity in gallons per minute	Horse power required for each foot of lift, minimum quantity	Diameter and face of pulley in inches	Price of horizontal iron pump	Price of vertical iron pump
No. 1½	20 40	160	.063	5x 5	$ 35	$ 30
" 1¾	40 60	225	.085	6x 6	50	40
" 2	60 80	325	.126	7x 8	70	60
" 2½	80-100	400	.190	7x 8	80	70
" 3	120 180	675	.270	7x 8	95	75
" 4	200 300	1300	.425	8x10	130	110
" 5	350 500	1900	.504	10x10	165	140
" 6	500 700	2700	.765	12x12	200	170
" 8	900 1300	4800	1.10	18x12	310	265

OBSERVATION.

1st. When a large quantity of water is to be handled, as in draining land, or in supplying water for irrigation, and the height water is to be raised is less than 25 feet, best results will be obtained by using one large cylinder (size given in table), and using for discharge and suction pipe same size as the diameter of cylinder.

2nd. When one cylinder of sufficient diameter cannot be obtained, then two or more cylinders may be substituted. Each cylinder requires a separate discharge pipe.

3rd. Lift pumps are best adapted to irrigation and drainage.

4th. For irrigation, where water is to be stored in an elevated tank and where a lift pump cannot be used successfully, a force pump may be used..

5th. Discharge pipe should never be less than one-half the diameter of cylinder in all depths of wells, and the more nearly the discharge pipe equals the cylinder in diameter, the better the results.

6th. Back geared mills give best results when working on intermediate or longest stroke.

PUMPING CAPACITIES OF WIND MILLS.

LIFTING WATER	8 foot Back Geared has 6 and 8 in. stroke	No. of Cylinders to use	Diam'r of Cylinders to use	Diameter of Discharge pipe	10 foot Back Geared has 6, 8 and 10 in. stroke	No. of Cylinders to use	Diam'r of Cylinders to use	Diameter of Discharge pipe	12 foot Back Geared has 9 and 12 in. stroke	No. of Cylinders to use	Diam'r of Cylinders to use	Diameter of Discharge pipe	14 foot Back Geared has 7, 9½ and 12 in. stroke	No. of Cylinders to use	Diam'r of Cylinders to use	Diameter of Discharge pipe
5 feet	150 bbls 4700 gal. per hr.	1 or 2	in. 12 8	in. 8 6	244 bbls 7332 gal. per hr.	1 or 3	in. 15 8	in. 10 6	354 bbls 10,622 gal. per hr.	1 or 5	in. 18 8	in. 12 6	500 bbls 5000 gal. per hr.	1 or 8	in. 24 8	in. 16 6
10 feet	78 bbls 2350 gal. per hr.	1 or 2	9 7	6 5	122 bbls 3666 gal. per hr.	1 or 2	10 7	6½ 5	177 bbls 5311 gal. per hr.	1 or 3	12 8	8 6	250 bbls 7500 gal. per hr.	1 or 4	18 8	12 6
15 feet	51 bbls 1566 gal. per hr.	1	7	5	81¼ bbls 2444 gal. per hr.	1	8	6	118 bbls 3540 gal. per hr.	1 or 2	10 8	6½ 6	166⅔ bbls 5000 gal. per hr.	1 or 3	15 8	10 6
25 feet	31 bbls 910 gal. per hr.	1	5½	3	44 4-5 bbls 1466 gal. per hr.	1	6	4	71 bbls 2124 gal. per hr.	1	8	6	100 bbls 3000 gal per hr.	1 or 2	10 7	6½ 5
50 feet	15½ bbls 470 gal. per hr.	1	4	2	24 2-5 bbls 733 gal. per hr.	1	4½	2¼	35 2-5 bbls 1062 gal. per hr.	1	6	4	50 bbls 1500 gal. per hr.	1	7	5
75 feet	10 bbls 310 gal. per hr.	1	3¼	1½	16 bbls 488 gal. per hr.	1	3½	2	23⅓ bbls 710 gal. per hr.	1	5	3	33⅓ bbls 1000 gal. per hr.	1	6	4
100 feet	8 bbls 235 gal. per hr.	1	2¾	1¼	12 bbls 366 gal. per hr.	1	3	1½	17⅔ bbls 531 gal. per hr.	1	4	2	25 bbls 750 gal. per hr.	1	5	3
125 feet	6 bbls 188 gal. per hr.	1	2½	1¼	9⅔ bbls 293 gal. per hr.	1	2¾	1½	14 bbls 424 gal. per hr.	1	3¾	2	20 bbls 600 gal. per hr.	1	4½	3

150 feet	5 bbls 150 gal. per hr.	1	2¼	1¼	8 bbls 244 gal. per hr.	1	2½	1¼	11⅔ bbls 354 gal. per hr.	1	3½	2	16⅔ bbls 500 gal. per hr.	1	4	2½
175 feet	4½ bbls 125 gal. per hr.	1	2	1¼	7 bbls 210 gal. per hr.	1	2¼	1¼	10 1-30 bbls 303 gal. per hr.	1	3¼	2	14 4-15 bbls 428 gal. per hr.	1	3¾	2
200 feet	3 4-5 bbls 115 gal. per hr.	1	1¾	1¼	6 bbls 185 gal. per hr.	1	2¼	1¼	8¾ bbls 265 gal. per hr.	1	3	2	12½ bbls 375 gal. per hr.	1	3½	2
225 feet					5⅓ bbls 160 gal. per hr.	1	2	1¼	7¼ bbls 236 gal. per hr.	1	2¾	1½	11 1-10 bbls 333 gal. per hr.	1	3¼	2
250 feet					4 4-5 bbls 145 gal. per hr.	1	2	1¼	6⅔ bbls 200 gal. per hr.	1	2½	1¼	10 bbls 300 gal. per hr.	1	3¼	2
300 feet					4 bbls 120 gal. per hr.	1	1¾	1¼	5 5-6 bbls 175 gal. per hr.	1	2¼	1¼	8⅓ bbls 250 gal. per hr.	1	3	2
350 feet									5 bbls 150 gal. per hr.	1	2¼	1¼	7 1-6 bbls 215 gal. per hr.	1	2¾	1½
400 feet									4⅓ bbls 130 gal. per hr.	1	2	1¼	6 1-6 bbls 185 gal. per hr.	1	2½	1½
450 feet									3⅓ bbls 100 gal. per hr.	1	1¾	1¼	5½ bbls 165 gal. per hr.	1	2½	1½
500 feet													5 bbls 150 gal. per hr.	1	2½	1½

Above estimates are based on 12 to 15 mile wind per hour and mill placed directly over well, mill working on intermediate stroke.